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Second Edition

John Thomas Berry

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The Waite Group's

Inside the Amiga® with C

Second Edition

John Thomas Berry

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This book is dedicated to my mother, Dorothy Berry, not least for teaching me the importance of education, and to my father, Theron Berry, who taught me the importance of hard work.

John Thomas Berry

Contents

Preface ix

Acknowledgments x

Chapter 1 Introduction 1
Overview of the System *3*
The Hardware Architecture *4*
The Software Architecture *5*
The Organization of the Book *7*
A Note About the Example Programs *8*

Chapter 2 The Amiga Programming Environment 9
Software Components *11*
System Access *14*
Specialized Amiga Data Types *25*
Summary *27*

Chapter 3 Using Intuition 29
Intuition *31*
Windows and Screens *32*
Modular Programming *62*
Gadgets *65*
Menus *76*
Requesters *92*
Alerts *95*
Intuition I/O *97*
Building an Intuition Library *106*
A Final Note on Programming Style *112*
Summary *114*

Chapter 4 Process Control and AmigaDOS 115
Multitasking *117*
AmigaDOS *126*
Using Workbench to Start a Process *132*
Summary *143*

Chapter 5 Drawing in Intuition 145
Intuition-Supported Graphics Functions *147*
A Practical Gadget Library *176*
ROM Kernel Graphics Commands *182*
Some Miscellaneous Functions *201*
A Simple Drawing Program *207*
Summary *210*

Chapter 6 Animating the Sprites 211
Sprites *213*
Defining a Sprite *214*
Color and the Sprites *219*
The Simple Sprite *220*
Animating GELs Objects *236*
Summary *264*

Chapter 7 Programming Sound 265
Creating Sounds *267*
Computerized Sounds *269*
Creating Sound on the Amiga *271*
Accessing the Audio Device *274*
Multichannel Sound *297*
Summary *307*

Chapter 8 Artificial Speech 309
The Nature of Speech *311*
The Translator Library *312*
The Narrator Device *315*
Experimenting with the Narrator *328*
Summary *346*

Chapter 9 Programming with Disk Files 347
The File Management System *349*
The Notion of a File *350*
Practical File I/O *352*
File Maintenance Functions *356*
Files and Multiprocessing *358*
Disk Update Functions *360*
Directory Maintenance *365*
Device File Functions *370*
Summary *372*

Index 373

Preface

The Amiga is the first of a new wave of small computers. This machine combines the convenience of a personal computer with the kind of performance that has, until now, been found only on larger systems.

The Amiga is an easy machine to program, particularly in light of its power. However, its flexibility presents the software developer with a great many subsystems, details, and options.

In this book we will explore each of the major subsystems through concrete examples. Each example is meant to demonstrate a particular feature or detail of the machine and its operating environment. These example programs can then form the core of a library of functions to allow access to the Amiga's system services.

Some of the topics we will cover include:

- Access to the Amiga's three operating systems—Intuition, AmigaDOS, and the executive kernel—using the language C
- Creation and manipulation of windows, screens, gadgets, menus and other Intuition objects
- Multiprocessing under AmigaDOS, including ports and messages for communication between processes
- Amiga's powerful graphics capabilities for line drawing, area fill, polygon drawing, and text fonts
- Animation with hardware sprites
- Sound programming in both monaural and stereo, through the audio device
- Speech synthesis and the narrator device
- File management with AmigaDOS

The Amiga is an ideal environment for the programmer. Access to the system is through the C programming language, and all of our examples are in this language. Furthermore, the Amiga software environment is more like

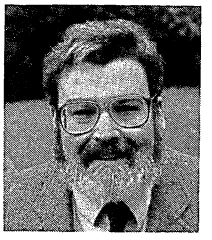
that of a large computer. Each subsystem of the machine is accessed not through a hardware-specific location but as a software object. Thus, we have the audio device, the narrator device, and the console device, to name just a few major ones. The examples in this book show how to handle this kind of programming.

Once the you finish this book, you will be in a position to write mature and exciting software for this multifaceted machine. No prior experience with system programming is necessary. Familiarity with the C language is assumed, but expertise is not required. In fact this book can serve as an excellent vehicle for perfecting knowledge of this most important programming language. However, first and foremost, this is a book about programming the exciting Amiga.

Acknowledgments

Let me take this opportunity to thank those who have helped me finish this enormous task: First to my wife Nancy and my daughter Rebecca an acknowledgment of their infinite patience and love; to Kim House, my favorite editor, and to Jim Stockford, my favorite taskmaster, for helping me keep the book on schedule; to Jerry Volpe for getting the project started; and finally, to the guys on the Well, for helping me to understand the Amiga and its many uses. And special thanks go to Andy Finkel of Commodore-Amiga for reviewing the text and making valuable suggestions that have made it a better book.

About the Author



John Berry has been actively involved with computers and the software industry since 1975. In that time he has worked on such diverse projects as an accounting system for a Las Vegas casino and an information management system for a large European hotel and convention center. He has been teaching programming and computer science since 1979 and now divides his time equally between teaching, writing, and consulting. Mr. Berry attributes most of his success to his wife Nancy and his daughter Rebecca.

Introduction Chapter 1

Overview of the System
The Hardware Architecture
The Software Architecture
The Organization of the Book

Overview of the System

Welcome to the world of the Amiga microcomputer. This system is easily the most sophisticated small computer in its price range. It offers:

- Superb graphics capability
- Quality audio circuitry with a software control system to support it
- A built-in speech synthesizer
- A multiprocessing operating system

In addition, two types of user interface are supplied:

- A windowing system whose focus is a mouse that can point at a display crowded with menus, gadgets, and other icons
- A more traditional terminal-like interface with system commands and I/O redirection

Furthermore, the terminal-like interface can exist in a window that shares the screen with other windows. The Amiga is a user's machine.

The Amiga is also a programmer's machine. Every effort has been made to facilitate access to what is an extremely complex system. This is possible through a software support system that is actually three interacting operating systems. Wherever possible, implementation details are separated out in a hierarchy of service routines, so that the software designer can go as deep into the machine architecture as is necessary to produce the desired result. Throughout the system, defaults are set up to take care of details that do not need to be dealt with intimately.

The multiprocessing capability of the Amiga puts it in a class beyond most small computers. One important thing that experienced programmers miss when they make the transition from large mainframe or minicomputers to small systems is the ability to run more than one task at a time. From a productivity standpoint, the advantage is obvious. You can do a compile in

the background while editing another file. You can search a database at the same time as you create a document. You can even send a long output to the printer and perform other tasks while the printer is executing.

But beyond questions of productivity and convenience, multiprocessing affects the way you design applications. For example:

1. A database program might perform long searches as a coprocess with its interactive query language interpreter.
2. A text formatting program could process a file at the same time it accepts input from a user.

These simple examples help to illustrate the differences that programming under this kind of environment makes possible. You are not, however, forced to program in any particular way on the Amiga, especially when no effort has been expended to enforce a common interface. You do not even have to take advantage of the system's multiprocessing capabilities, but can write perfectly acceptable programs in the old-fashioned way—one application in memory at a time. Of course, even then you are using multiprocessing, because the system programs run in the background.

The Hardware Architecture

The hardware architecture of the Amiga is unique. Common among small computer systems is the traditional single central processing unit (CPU), which controls all activities of the machine. Input and output, memory management, and the disk drive interface—all must go through this single processor. The Amiga, in contrast, has a powerful CPU—the Motorola MC68000—but it also has a coordinated group of coprocessors and other support circuits to handle more specialized tasks. Not everything is handled by the main processor.

These specialized devices include:

- The *copper*, another general purpose processor that controls the graphics system
- Eight *sprite processors* that control the movement of these graphics objects in the display field
- The *blitter*, a device specialized to both move and combine data from one part of memory to the other

In addition to these processors, there are a number of support circuits that perform tasks in tandem with the main CPU.

- The audio system consists of four digital to analog converters that give the user maximum versatility in creating sounds.
- Thirty-two color registers are provided, each of which can be assigned any of 4096 possible colors.

The design philosophy of the Amiga has been to specialize the hardware wherever feasible, trusting that this will produce the most efficient design.

The organization of these support processors and circuits adds to their efficient operation. The Amiga is a bus-oriented system. Each coprocessor, each support circuit is on the bus. Most have independent access to the main memory through the bus—they are DMA (Direct Memory Access) driven. Furthermore, the system clock is arranged so that every other cycle is given to these specialized chips. The speed differential between the main CPU and the memory is such that, even accessing the bus only every other cycle, the CPU is running at full clock speed. Thus, true parallel operation occurs most of the time on the Amiga.

This DMA organization follows through to device drivers. The disk drive can transfer data directly between memory and a floppy diskette. There is no need to go first through the CPU. The input/output system is similarly arranged. This kind of organization is another feature found previously only on large computers. There are some restrictions on the DMA subsystem. The Amiga is capable of addressing up to eight megabytes of memory directly, but only the first 512 kilobytes are available to the specialized hardware.

The Software Architecture

The Amiga is really a software driven machine. There are no absolute memory locations or hardware addresses where certain key values are stored. System services are not accessed by changing memory locations. Since this is a multiprocessing system, we can never guarantee the absolute location of even key system software. Everything must be specified relative to the location of some anchor value in memory. Access to system routines is almost solely through software.

As mentioned earlier, the Amiga operating environment really consists of three cooperating but disparate operating environment:

1. The *executive kernel* is the most basic; it is minimal operating system supporting memory allocation, communication between processes and devices, low-level multitasking, and the primary input/output functions.
2. *AmigaDOS* is a traditional operating system, responsible for the file management system and high-level multiprocessing support.
3. *Intuition* is the icon-oriented, window-based system that is the primary interface for users.

Most executive kernel calls are beyond the scope of this book. A chapter is devoted to both AmigaDOS and Intuition.

The executive, as the lowest level, supports both of the other two components. The relationship between AmigaDOS and Intuition, however, is not as straightforward. This will be discussed again later in the book; a brief summary is all that can be given here. AmigaDOS is the next most basic operating system, supplying user-accessible services, particularly those related to the file system (e.g., directory displays and file manipulation commands). Intuition depends upon AmigaDOS to supply it with a file system; therefore,

in this sense it is dependent upon AmigaDOS. However, there is not a clean hierarchy. Intuition also takes services directly from the executive, independent of any other subsystem. In practice, this complicated situation is not a problem for either the software developer or the user.

The programmer can easily move through all three levels of the operating system environment and use services from each one in an application; they are not mutually exclusive. This capability allows powerful software to be easily and quickly designed. If a particular system routine is not effective, it can be rewritten in terms of lower-level modules, without rewriting the entire application on a basic level. Machine level is accessed only when necessary and then only to the extent that is necessary.

Access to the System Software

The Amiga continues a modern trend in systems programming. Although assemblers are available for the MC68000 microprocessor and even for its configuration in the Amiga, the primary means of programming is through the high-level language C. There are many advantages to system programming in C. There is the great increase in productivity that always accompanies a move away from a machine specific programming language—each high-level statement represents more than one machine instruction. On the Amiga, using C helps the programmer deal more adequately with the inherent complexity of the machine. The level of hardware parallelism and the interacting coprocessor architecture almost require the abstraction offered by a compiled language such as C. Since the Amiga is a software dominated system, a means of accessing the system resources is needed. Each important object, whether hardware or software based, has an associated C structure data type. These structures are the programmer's hooks into the machine. In some cases, they allow very low-level access; one structure consists of hardware registers for the specialized chips. Much effort in each chapter will be spent describing these data objects.

The operating system services are accessed by C function calls. All three environments define their own sets of such functions optimized to their particular needs. For example:

- *OpenWindow()* creates this Intuition object on the display field.
- *Date()* returns values for the system clock maintained by AmigaDOS.
- *Wait()* enables the executive kernel to suspend a task while waiting for a message at its port.

These are just examples. In the chapters that follow, we will be incorporating many such system functions in example programs.

You do not lose efficiency in using C. The operating system environment presupposes C as the support vehicle for systems programming. Most of the utility programs are written in this language, as well as a large number of existing applications. As C compilers become more sophisticated and more capable of optimizing their output, this situation can only improve.

The Organization of the Book

In this book, we hope to cover the principles and techniques that will allow the moderately skilled programmer to write large and mature applications taking advantage of the Amiga's powerful hardware and software. We cannot cover everything—that would create a truly encyclopedic work. We have tried to give the programmer insights into the Amiga's major subsystems and also a feeling for its design philosophy. After finishing the book, you should be in a position to deal with the Amiga and to discover even more of its secrets.

Each chapter in the book focuses on a particular subsystem. The basic objects and functions that define and manipulate that subsystem are explored.

Chapter 2 considers the programming environment offered under the three operating systems and discusses some of the peculiarities of using C on the Amiga.

Chapter 3 takes a long look at Intuition. It shows how to define windows and screens, and explores the notions of gadgets and menus.

Chapter 4 is devoted to multiprocessing under AmigaDOS, defining the notion of a process and explaining how to manipulate it under this operating system.

Chapter 5 explores the graphics capability of the Amiga, showing how to access the hardware support routines for such things as area fill and polygon drawing.

Chapter 6 concentrates on the hardware sprites. These are small graphics objects that can be moved independently of the rest of the Amiga graphics display system.

Chapter 7 gives access to the audio channels through the audio device. Programming in both monaural and stereo is covered and the flexibility of this device is revealed.

Chapter 8 teaches how to make the Amiga talk. Access to the two-part speech synthesizer is covered.

Chapter 9 returns to AmigaDOS to discuss the file management system.

Each chapter focuses on the essential set of structures and functions that will allow the programmer to use that subsystem to create useful designs.

It is assumed that the reader is familiar with the C programming language. No tutorial efforts are offered in this book, but example programs, for the most part, avoid the more obscure aspects of the syntax. This is not through any prejudice for or against a particular programming style. The example programs have one goal and that is to illustrate particular aspects of the Amiga. While the example programs tend to be simple and straightforward, there is no presumption or argument that production code need follow this rule.

The examples in the text are to be used as guides; each has been designed to represent a particular subsystem of the Amiga, usually a single feature. These programs should be studied and duplicated, but above all, they should serve as a springboard for more complex software. It is a truism that the only way to learn programming is to program, and it is doubly true on the Amiga. Each program should serve as the basis for a series of experiments, starting with code that is known to work and having as a goal some personal design. Often these programs can be easily merged to produce a more complex example.

A Note About the Example Programs

The main thrust of the programming examples throughout the text is to illustrate the methods by which each Amiga subsystem is accessed and controlled. In every case, the clear expression of ideas is the first priority. These programs can often be improved by the addition of explicit error checking and the use of more efficient programming constructions but at the cost of a more complicated and difficult to follow algorithm.

An important but secondary consideration is the level of expertise of the reader. While not an explicit tutorial in C, an expert's knowledge of this programming language is not required. Most of the obscure constructions in this language have been avoided—sometimes at a loss in efficiency. This book is designed to serve the individual who is just learning to program in C as well as the more experienced programmer.

A complete program should be efficient and contain explicit error checking. This is particularly true in the case of a multitasking environment such as the Amiga with many programs competing for limited resources such as memory. The reader should be careful to include these considerations in the design of his or her own programs.

Finally, all of the examples in this book have been designed and tested to run on an Amiga system with 512 kilobytes of memory. This is memory that can be directly accessed by the specialized coprocessors; called chip memory, it must be distinguished from any additional expansion or fast memory. The latter can be used by any C program but not by the specialized hardware. Care must be taken when creating variables or allocating memory that only chip memory be used for graphics or other specialized subsystems. There are also public domain programs that will correct existing programs that do not perform properly in expanded systems.

The Amiga Programming Environment

Chapter 2

Software Components
System Access
Specialized Amiga Data Types
Summary

The programming environment on the Amiga is designed to allow high-level access to the system resources. This access is accomplished primarily through the C programming language, using data objects defined within its syntax. This chapter will discuss how C is used to make these definitions and access the operating system. This discussion will serve as a general introduction to material which will be covered in greater detail in succeeding chapters. Use of the Lattice C compiler is assumed. The files and techniques peculiar to this implementation of the language are detailed.

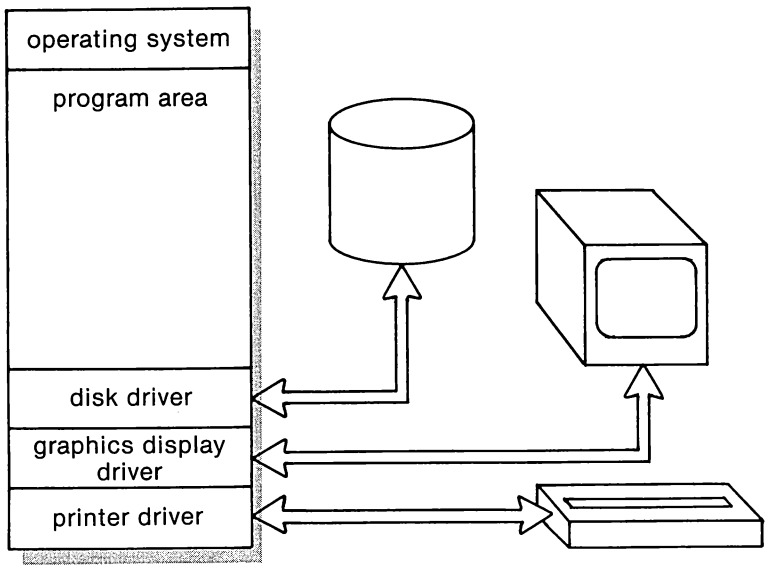
Software Components

The Amiga is a complex computer with many interlocking hardware resources. The blitter, sound subsystem, and hardware sprites are just a few. This complexity is necessary to create a programming engine with the power to match the Amiga, but it also requires a correspondingly rich software environment to make the full power of these subsystems available to the user. The programmer must be able not only to get at the lowest levels of the machine, but also to coordinate the operation of many simultaneously operating parts.

Traditionally, access to the lowest levels of the computer have been via assembly language routines that access absolute hardware locations. The programmer must know the absolute physical address of each subsystem and how to activate and control it (Figure 2-1). Each has a unique set of values and its own commands, and each interacts with the other resources in numerous ways. The programmer must face the complexity of this situation.

The Amiga, in contrast, shields the programmer from this multifaceted task of hardware integration. Instead, a consistent and high-level interface is presented. As much as possible, each resource, whether hardware device or software subsystem, is accessed in a similar way. The same command set is used and similar kinds of data structures are created to pass values back and

Figure 2-1. Traditional methods of accessing hardware resources



forth. Differences are represented by new interpretations of individual commands and by passing different values to an object. A write command to a disk drive will put something on a disk, while the same write command to an audio channel will result in the production of a sound (Figure 2-2). This consistent interface increases flexibility in another dimension: redirecting output from one device to the other is greatly simplified.

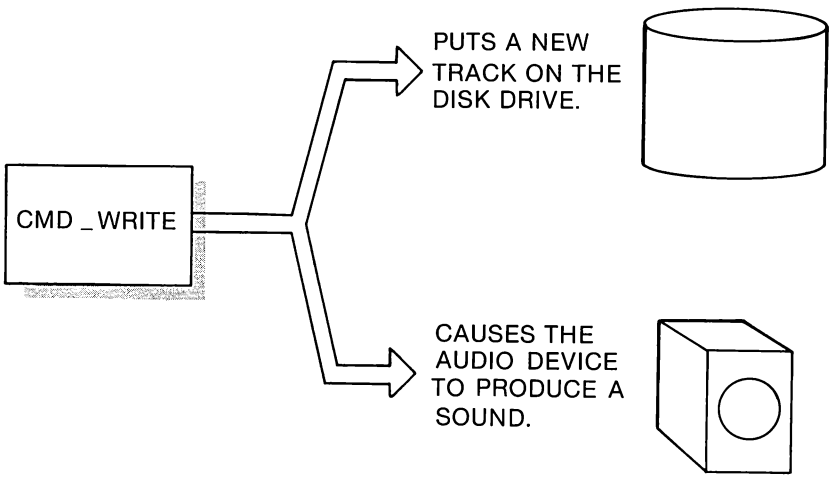
To create this shield, the Amiga has a multilayered operating system. Each layer performs its own set of duties, presupposing the services of lower-level functions and supplying the necessary objects for higher-level ones. However, it must be emphasized that this is not a strong hierarchy, as is commonly found in multitasking operating systems. The programmer is free to utilize any level of the Amiga's software environment and even, with some reasonable restrictions, to mix levels.

The three main components of the Amiga's operating system environment are:

1. The executive kernel
2. AmigaDOS
3. Intuition

These represent not only three different operating environments to the software designer, but also different philosophies of design. Furthermore, each has its strengths and weaknesses. Intuition is the primary operating system for the Amiga. This is the one designed for the user of software. It is a visual interface with windows and pop-down menus, all controlled by a

Figure 2-2. Commands will have different interpretations when applied to different devices



mouse. Its name describes the philosophy of its design: it is meant to be an intuitive command shell. A user should be able to access the Amiga through Intuition with only minimal outside instruction. For the programmer, Intuition is the most complex of the three operating systems to deal with.

AmigaDOS is a more traditional operating system. Organized around a command line interpreter that is reminiscent of the UNIX shell, this will seem more familiar to the experienced programmer. Two important subsystems are defined in this operating environment:

1. The file management system
2. The high-level multitasking system

Both of these topics need further elaboration and, in fact, a chapter is devoted to each. Suffice it to say here that things such as the directory and format for each kind of file are defined as a part of the AmigaDOS operating system. The notion of a process and the loading and unloading of software segments are integral parts of this DOS environment. Most software development is done in this familiar environment.

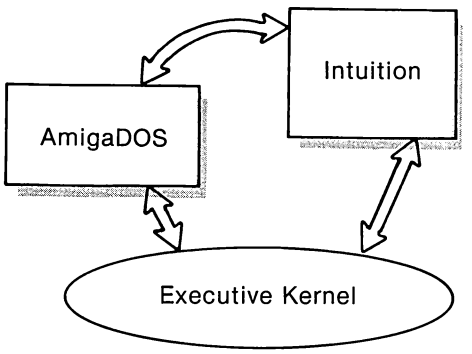
At the lowest level of the Amiga's software architecture is the executive kernel, the most basic operating system. In fact, the other two operating systems—Intuition and AmigaDOS—rest upon it (Figure 2-3). The two primary duties of this subsystem are:

1. To provide a message sending system to support multitasking
2. To handle low-level, device-specific input and output

In many operating systems, this level would be unavailable to the programmer, but with the Amiga it is not only available, but access to it has

been simplified. The executive kernel consists of a series of service functions that are easily called from any C program.

Figure 2-3. AmigaDOS and Intuition and their relationship to the executive kernel



System Access

As with most modern computer systems, the Amiga is accessed through a high-level programming language, in this case the language C. C is an ideal programming vehicle particularly for small, complex systems. It has a small but powerful syntax that is ideal for the concise expression of complicated instructions. Most C compilers—including those available for the Amiga—produce reasonable if not optimal machine code.

No real compromise is made in abandoning the more traditional assembly language for the greater productivity of a high-level language. In the case of the Amiga, the software development environment is set up to presuppose programming in C. The gains made are great indeed. Since C readily and easily allows the linking of externally defined functions, any critical sections can still be rendered through an assembler and linked into a C program.

Each important subsystem of the computer has a corresponding object—usually a set of objects—defined in terms of a C structure data type. Some of these objects are shown below. A great part of what follows will be devoted to exploring these structures and seeing how they combine together to make the Amiga do its amazing feats.

Examples of structures used to represent operating system objects

```
struct IORequest  {
   struct Message  io_Message;
   struct Device   *io_Device;
```

```
    struct Unit     *io_Unit;
    UWORD           io_Command;
    UBYTE           io_Flags;
    BYTE            io_Error;
};

struct IOStdReq {
    struct Message  io_Message;
    struct Device   *io_Device;
    struct Unit     *io_Unit;
    UWORD           io_Command;
    UBYTE           io_Flags;
    BYTE            io_Error;
    ULONG           io_Actual,
                    io_Length;
    APTR            io_Data;
    ULONG           io_Offset;
}
```

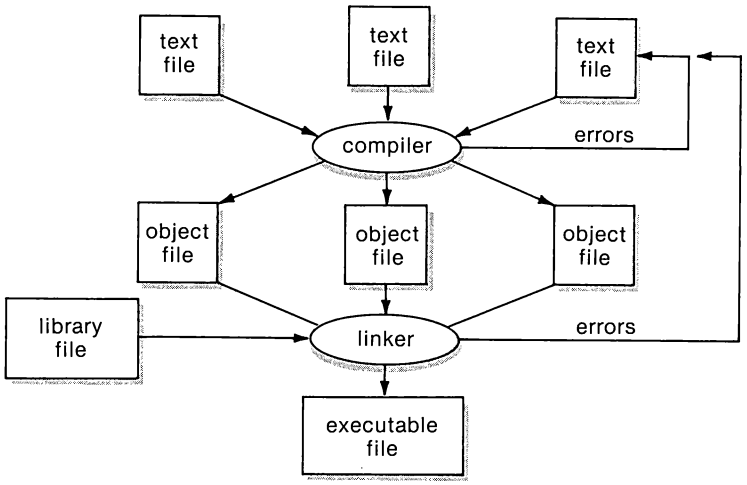
Using C

Figure 2-4 briefly reminds us of the functions performed by a C compiler. The most important function is to take ordinary text files containing C programming statements and to translate them into executable machine instructions. Subsidiary functions include error checking and the production of source listings. The C compiler on the Amiga works in conjunction with a linking editor or linker, ALINK, to produce the final loadable program modules. We presuppose the Lattice C compiler, as this was the first available for the Amiga. Different compilers may not conform to the same command sets and sequences. Producing a program on the Amiga is a three stage process:

1. Edit to produce a text source.
2. Compile to get an object file.
3. Link to an executable file.

Each one of these stages uses an independent program to accomplish its

Figure 2-4. Compiler as a production engine



goal. The choice of a text editor is a personal decision with most programmers. A number are available for the Amiga. The compiler and the linker, however, are less open to choice; therefore, it seems appropriate to discuss their operation.

Lattice C

In this section specific implementation details will be discussed, so what follows immediately may not be applicable to other compilers. However, what follows in the rest of the book is the same for all versions of C.

The Lattice compiler is divided into two phases. Each phase can be invoked separately through its own command line:

1. *LC1* starts the first phase of the compile.
2. *LC2* begins the second phase.

In the first phase, a source file containing C statements is processed to produce an intermediate file. Among the tasks performed in this initial phase are:

- Preprocessor command execution
- Symbol table creation

The second phase takes the intermediate file produced earlier and creates an object file. The intermediate file is then removed from the disk. This object file contains a mixture of machine code and linkage information; it is not yet ready to execute.

Each stage of the compilation is invoked with a unique command line. For the first stage, the format is:

```
LC1   >listing_file   toggles   file_name
```

where

listing_file names a disk file that will accept all messages including messages that would ordinarily be sent to the screen. This is an optional part of the command line and must be a fully qualified file. No default values are defined.

toggles represents a list of compiler toggles that control the action of the compiler and can change some default values. This too is an optional part of the compiler command line.

file_name indicates the source code file. Note it need not end in *.c* but if no extension is explicitly mentioned, this will be assumed.

The only requirement for starting a compile is that the source file name must be given, although optional arguments to the command line may help in the development process.

A complete list of the compiler toggles for the first phase of compilation is shown below. Among the more commonly used ones, we find:

-d puts debugging hooks into the intermediate quad file. These can then be used later by an optional debugging program.

-dname is equivalent to a *#define* statement in the source file. It can be used in conjunction with the *#ifdef* or *#ifndef* preprocessor statements.

-i forces data elements to be aligned on long word (32-bit) boundaries. This alignment is important for compatibility with AmigaDOS structures.

-p produces a file with the extension *.p*, that contains the source code along with the full expansion of the preprocessor statement. No executable file is produced.

-oo_name gives the object file produced by the compiler a name different from the source file.

First pass compiler toggles

-b	this causes all static and external data references to go through a base register (A5 or A6).
-c<flags>	these control compatibility with earlier versions of the compiler. Flags may be concatenated with no white space between them
c	allows nested comments.
d	$ may be embedded in identifiers.
m	mulitple character constants allowed.
s	generates only a single copy of identical string constants.

```
        u           forces character declarations to be unsigned.

        w           no warning for return statements not specifying a
                    value.

-d                  puts debugging information in the object file.

-d<name>            equivalent to #define <name>.

-d<name>=<value>    equivalent to #define <name> <value>

-i<name>            attaches <name> to any file in a #include statement
                    except those already prefixed by a / ,\, or a
                    period. Up to four such names may be specified in
                    separate -i clauses.

-l                  all data items except short and char will be long
                    word aligned.

-n                  truncates identifiers from 32 to 8 characters.

-o<name>            causes the quad file to be called <name>.

-p                  causes a file with extention '.p' to be produced that
                    contains the expansions of the preprocessor commands.
                    No quad file is produced.

-u                  automatic symbol definitions are cancelled.

-x                  the storage class for externals is changed from
                    external definition to external reference.
```

Compiler toggles are invoked just as they have been represented here, prefaced by a hyphen and surrounded by white space. For example, to compile a file named *src.c*, but create an object file named *obj*, and to make sure that all data is lined up on long word boundaries, the following command line would be used:

```
LC1  >df1:err_list -oobj   -l  src.c.
```

Note that we have given the full file name for the list file. The second phase of compilation has a similar command format:

```
LC2   toggles   file_name
```

Here **file_name** refers to a file with a *.q* extension, produced by the *LC1* phase of the compiler. A different set of toggles controls this stage.

-oo_name creates a different name for the object file produced by the compiler. It is similar to the toggle in the first phase.

-r makes all addressing relative to the program counter. This restricts the addressing range to 64K around this register, but is necessary to produce position independent code.

A complete listing of the second stage compiler toggles is shown below.

Second pass compiler toggles

-fn	specifies register A5 (n=5) or A6 (n=6) as the stack frame pointer.
-o<name>	changes the name of the output file to <name>.
-r	causes the addressing to be PC relative; this limits addressing range to 132k. This is used for creating position independent code.

Invocation of this stage is similar to that of LC1.

```
LC2  -oobj  src
```

This command creates an object file *obj.o* from the intermediate file *src.q*. Note that there is no option for an error listing file in this second phase.

The compiler will report errors whenever it finds them. A successful compiler during the first phase will report nothing back to the screen. However, at the end of the second phase, the size of the resulting code will be displayed to the user in the form:

```
Module size  P=9999  D=9999  U=9999
```

where

P indicates the size of the executable code segment.

D is the size of the initialized data module.

U reports on the uninitialized data area.

All measurements are in bytes and are written in hexadecimal.

Lattice C contains a compiler driver or shell that will automatically invoke both phases of the compiler. It takes the general form:

```
LC   toggles   file_name1 file_name2...
```

Each file name must be separated from the others by white space.

The toggles list is created by a mixture of options from either phase as well as two toggles peculiar to this command line form. Only one argument is ambiguous: *-oo_name*. This ambiguity can be resolved by using *-qx* in place of *-o*. This form can also be used to change the default location for the quad file—it is automatically put in the RAM disk (RAM:). The *-v* command options make Lattice C verbose, displaying each line as it is executed.

Finally, Lattice C comes with an object modular disassemble, OMD, to help in debugging. This utility program provides a list of machine language

instructions generated by a C program. It is invoked with the following command line:

```
OMD  Qlist_file  toggles  object_name  source_name.
```

where

list_file specifies a target location for the file produced by OMD. The default is the screen.

toggles represents commands to change the default setting of the program parameters:

object_name is the file that is the source of all the attention.

source_name specifies the source file from which the object file was produced.

-X9999 sets the maximum number of external items that can be dealt with by the utility. The default is 200.

-L9999 sets the maximum number of lines. Here the default is 100.

If the file was compiled with the *-d* option, a complete listing with both source and machine language is produced.

The Linker

The two passes of the compiler produce an object code that is not yet ready to be loaded and run. It contains some directly executable machine code, but also references to functions and variables in other files and to library routines. All of these external references must be reconciled and the actual code loaded into the final executable program file. This final setup task is the job of ALINK, the Amiga's linker utility.

ALINK will accept several different kinds of files and will produce an executable object module. There are two basic file types that must be offered to ALINK as input:

1. **Primary binary input files.** These are the object files produced by the compiler. Any number can be combined to form a single executable program.
2. **Library files.** These, in contrast to the primary files, are precompiled functions. They may be part of a standard library or one created specifically by the user.

These are the basic files from which the executable module will be constructed.

ALINK is a two pass compiler. The first pass:

- Reads through the primary input files and the libraries recording the code segments
- Notes the external symbol information

- Creates the optional symbol map and cross reference table

The second pass is executed only if an executable file was explicitly specified. The default is not to produce this file.

During this final stage:

- The contents of the primary input files are copied to the output file.
- The necessary routines from the libraries are also copied.
- All external references are reconciled. An error will terminate the linking process at whatever stage it is discovered.

Two specific, non-fatal problems will cause the linker to issue a warning.

1. If, at the end of the first pass, a symbol is still undefined, a warning message will be displayed and the symbol will be set equal to zero.
2. If a symbol is defined more than once, a warning will be issued and only the first definition will be used. (If a library routine is redefined, no warning will be given, but only the first definition will be used.)

To invoke the linker, the following command line must be typed:

```
ALINK FROM in_files TO out_file WITH c_files VER m_name
LIBRARY l_files MAP m_file XREF x_file WIDTH 99
```

where

in_files is a list of object files. Each file must be separated by a comma or a plus sign.

out_file is the name of the executable file.

c_files is a file containing ALINK parameter values.

m_name is the destination for the messages generated by ALINK. Default is the display screen.

l_files is a list of library files. As with the input files, each one must be separated by a comma or a plus sign.

m_file is the destination of the symbol reference map.

x_file is the name of the cross reference table.

WIDTH 99 indicates the size of the output line for the map and the cross reference table.

Not all of these parameters are required to produce an executable file. Only the input files, the output file, and the libraries need be mentioned explicitly. The other parameters are available as aids to the user. Note that it is necessary to type the ALINK command line as one long line, although it will not entirely fit on a single display line. A carriage return indicates the end of the command.

The WITH parameter allows creation of a command file which can then be used to control the execution of ALINK. This file can contain any or all of the other parameters along with their values. A single parameter and its value are placed on each line which is then terminated with a semicolon. This

command file would contain those parameters which are common to all compiles, perhaps the same libraries or the MAP or XREF options. Shown below are the contents of a typical file. Note that since ALINK ignores everything on the line after the semicolon, comments can be affixed to the file—another important programming aid.

Contents of a typical WITH file

```
LIBRARY  df0:lib/lc.lib+df0:lib/amiga.lib;  link both libraries.
MAP  df1:symbolmap.ref;  always put the map on the second disk.
XREF  df1:crossref.ref;  also the cross reference file.
WIDTH  3;                    format is 3 symbols across.
```

The MAP parameter allows creation of a map of the executable module that will be produced by the linker. It is compiled during the first pass. This link map contains a listing for each segment of the output file consisting of:

- The file name that was the origin of the segment (truncated to eight characters)
- The segment reference number
- The type of the segment—data, code, etc.
- The size

In addition to this entry, a list of symbols in the segment, along with their values, is printed in ascending order. An example of a partial listing is shown in Listing 2-1. The MAP parameter is optional.

Listing 2-1. Listing compiled by the MAP option to ALINK.

```
0. CODE.   Memory Type PUBLIC Total Size 0001CC.
Hunkname: text

File: LIB:LStartUp.obj
Program Unit: No Name
Base: 000000  Size: 0001CC

Symbol                          Value

_XCEXIT                         0000013A


1. DATA.   Memory Type PUBLIC Total Size 00005C.
Hunkname: data

File: LIB:LStartUp.obj
Program Unit: No Name
Base: 000000  Size: 00005C

Symbol                          Value
```

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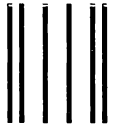

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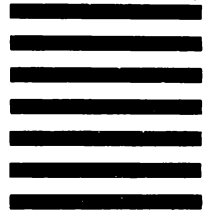

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Listing 2-1. (cont.)

```
_NULL                          00000000
__base                         00000004
__mbase                        00000008
__mnext                        0000000C
__msize                        00000010
__mstep                        00000014
__tsize                        00000018
__oserr                        0000001C
__fperr                        00000020
_console_dev                   00000028
_SysBase                       0000002C
_DOSBase                       00000030
_LoadAddress                   00000034
_WBenchMsg                     00000038
__StackPtr                     0000003C
__ProgramName                  0000004C
```

XREF produces a cross-reference table containing a listing for each symbol in the file and a list of references for that symbol. Each reference consists of a code segment number and an offset value into that segment. This linker option uses the same header format as the MAP. This is illustrated in Listing 2-2.

The WIDTH parameter specifies the output format for the MAP and XREF tables. It indicates the number of symbols printed per line. The default is a single symbol per line.

Listing 2-2. A partial listing compiled by the XREF option to ALINK.

```
0. CODE.   Memory Type PUBLIC Total Size 0001CC.
Hunkname: text

File: LIB:LStartUp.obj
Program Unit: No Name
Base: 000000  Size: 0001CC
Symbol                         Offset   Hunk   Offset   Hunk   Offset   Hunk

_XCEXIT                        00000058   56


1. DATA.   Memory Type PUBLIC Total Size 00005C.
Hunkname: data
File: LIB:LStartUp.obj
Program Unit: No Name
Base: 000000  Size: 00005C
Symbol                         Offset   Hunk   Offset   Hunk   Offset   Hunk
_NULL
__base                         00000006    2
__mbase                        00000090   41
__mnext                        00000096   41
```

Listing 2-2. (cont.)

```
__msize                 0000008A  41
__mstep                 000000BC  44   000000CC  44
__tsize
__oserr                 000001D0  35   00000276  35   000002FA  35
                        0000036E  35   00000402  35   0000044A  35
__fperr                 00000008  70
_console_dev            00000478  35   00000492  35   000004C8  35
                        00000522  35   00000536  35   00000582  35
                        00000598  35   000005D8  35   000005F6  35
_SysBase                00000004  84   0000001C  84   00000034  84
                        00000048  84   00000060  84
_DOSBase                0000000C  83   00000024  83   0000003C  83
                        00000058  83   0000006C  83   0000007C  83
                        00000094  83   000000AC  83   000000C4  83
                        000000D8  83
_LoadAddress
_WBenchMsg              0000014A  76
__StackPtr              00000002  75
__ProgramName           00000018  79
```

ALINK is a simple and straightforward program. It scans its input files and library files in the order in which they appear on its command line. In most cases, this has little effect on the final outcome of the process; however, in a few cases this can have a major effect. Earlier we noted that if a symbol has multiple definitions, only the first definition is valid. Thus, if files are linked with different definitions for the same symbol, the later definitions will have no effect. This is a problem when dealing with libraries, since redefinitions here are not even tagged with a warning message.

The Amiga system software supplies two libraries which are both typically linked to all programs.

lc.lib is the most general library and contains the routines from the standard library, as well as more specialized functions.

amiga.lib contains code for the AmigaDOS functions.

It must be noted that some AmigaDOS functions have the same name as those in the standard library. If the usual practice of linking in *lc.lib* and then *amiga.lib* is followed, the standard library will mask the AmigaDOS functions. Whenever working directly with this latter operating system, it is necessary to link *amiga.lib* first or, as is more common, to make it the sole library linked.

A similar caution involves the input files. Here the system supplies two object modules that, in turn, supply start-up and initialization code.

LStartUp.obj is a general purpose start-up routine—used in most cases.

AStartUp.obj is used to access AmigaDOS.

One of these modules must be the first file in the list of input files. This

is start-up code and must come at the beginning of the program. This file must be the first one read and transferred to the output. Following are some typical ALINK command lines.

Typical ALINK Command lines

```
Simple link:

   ALINK FROM LStartUp.obj+df1:demo.o TO df1:demo LIBRARY lib/lc.lib+
lib/amiga.lib

Full link:

   ALINK FROM LStartUp.obj+df1:demo.o TO df1:demo VER message LIBRARY
lib/lc.lib+lib/amiga.lib MAP df1:symbol.ref XREF df1:xref.ref

Link using a WITH file:

   ALINK FROM LStartUp.obj+df1:demo WITH df1:commands

Link for AmigaDOS:

   ALINK FROM AStartUp.obj+df1:demo.o TO df1:demo LIBRARY
lib/amiga.lib
```

Specialized Amiga Data Types

Access to the Amiga's system resource is supplied through software objects defined in terms of C syntax rules. The system also supplies a set of specialized data types to ease the programmer's plight and to enhance internal documentation. It must be emphasized that these are not really new types at all, but merely a renaming of data types standard to C. The new names help relate these types to the realities of the Amiga environment. For example, although type BOOL is really just a short integer, the word BOOL conveys that this value is a boolean, better than the more ordinary short designator. The advantage is really one of suggestion, but in a long and complex program, this can be quite valuable.

The creation of these new names is done with the *typedef* statement. The example type BOOL is created with the statement:

```
typedef  short  BOOL;
```

This is a form long familiar to C programmers. Of course, this has no effect on the data type *short*; it only alerts the system to the fact that there are now two distinct ways to declare a variable of this type.

The complete list of these special types can be found in Table 2-1. Among the more important and commonly used, we find:

LONG long

ULONG unsigned long

WORD	short
BYTE	char
UBYTE	unsigned char

Either form of these data types can be used in a program and the system will understand it. They may even be used interchangeably in the same file.

Table 2-1. Amiga data types

Amiga Types	Standard C Types
LONG	long
ULONG	unsigned long
LONGBITS	unsigned long
WORD	short
UWORD	unsigned short
WORDBITS	unsigned short
BYTE	char
UBYTE	unsigned char
BYTEBITS	unsigned char
STRPTR	*unsigned char
APTR	*unsigned char
SHORT	short
USHORT	unsigned short
FLOAT	float
DOUBLE	double
COUNT	short
UCOUNT	unsigned short
BOOL	short
TEXT	unsigned char

One final note involves the implementation-specific details of Lattice C on the Amiga. The C language defines its data types in terms of the basic unit of storage—the computer word—and not with any absolute value. This means that the size of specific types is implementation-dependent; therefore, it is always a good idea to ask about this dependency before writing for a particular machine. These relationships are detailed in Table 2-2.

Table 2-2. Data element sizes for Lattice C on the Amiga

Data Type	Bit Size	Range of Values
char	8	−128 to +127
unsigned char	8	0 to 255
short	16	−32768 to 32767
unsigned short	16	0 to 65535
int	32	−2,147,483,648 to 2,147,483,647
unsigned int	32	0 to 4,294,967,295
long	32	same as int
unsigned long	32	same as unsigned int
float	32	±10E−37 to ±10E38
double	64	±10E−307 to ±10E308

Summary

This chapter has discussed the Amiga programming environment. It has explored the way in which this system offers access to the hardware resources and software subsystems of the Amiga. It has also discussed some of the problems and benefits of a multiprocessing computer system.

The basic operation of the compiler and the linker has been covered. You have seen their basic operation and some of the important options that they offer. The system's debugging facilities have been touched upon, including:

The OMD (Object Module Disassembler)

The MAP option to ALINK

The XREF option

Examples have shown how these might help a programmer quickly diagnose and repair software problems.

Finally, this chapter has discussed the specialized data types defined with the Amiga's software system, and you have seen how they might be used to enhance the internal structure of a program.

Using Intuition Chapter 3

Intuition
Windows and Screens
Modular Programming
Gadgets
Menus
Requesters
Alerts
Intuition I/O
Building an Intuition Library
A Final Note on Programming Style
Summary

Intuition is the window-based interface most often used to access the Amiga. It serves as a standard interface within which input and output can be conveniently generated and controlled. The resources available include *screens*, *windows*, *menus*, and user-manipulable icons called *gadgets*. In this chapter, we will discuss methods for generating these objects and interfacing them to user created programs.

Intuition

The basic philosophy of Intuition is well indicated by its name. It is meant to be an interface that offers the full range of operating system services yet requires the minimum amount of off-line study to master. Every aspect of the computer is meant to be transparent and obvious to the user. The main access channel is the mouse, although it could be any similar device, such as a joystick. These devices are typically used for pointing. Access is reduced to as few actions as possible.

Intuition is a world of screens and windows. The *screen* is the main visual object; within it certain key parameters such as font, color, and resolution are set. The *window* is the locus of most activity in Intuition. It handles input and output and contains the *gadgets*—specialized control objects. Both windows and screens can be freely moved around within limits set by the programmer.

The ease with which a user can manipulate the objects in Intuition, however, is not carried over to program writing. Of the three programming environments found on the Amiga—Intuition, AmigaDOS and the executive kernel—this is the most difficult one in which to develop software. Intuition is a very complex system which requires even small, simple programs to handle many display details. However, Intuition is and is meant to be the primary user operating system, and successful software will have to deal with it.

Intuition consists of a library of compiled code that contains executable copies of all of the functions that it offers as services. This library is different than the libraries commonly used by software developers to produce programs. These are typically disk files which contain the object code for useful functions. (The standard library always found with C is a good example.) Such libraries are used during the linking phase of a software translation to add the function code to the program as it is being translated into a binary object file. On the Amiga, in contrast, most of the machine specific libraries are not added to the programs that use them, but are loaded along with the program. If a function is needed, the program calls it in memory as an offset from the library's current address; this adds greater flexibility and efficiency. If two programs are both using Intuition, only a single copy need be loaded; neither program is bloated by extra code segments.

Because Intuition is a run-time library, it is necessary to load it before its functions can be accessed. A global variable is declared:

```
struct IntuitionBase *IntuitionBase
```

This variable will contain the address of the library after it is loaded into memory. Note that there is no option with this variable; it must be called IntuitionBase. The actual loading is done by a call to a system open function:

```
IntuitionBase=(struct IntuitionBase *)
   OpenLibrary(intuition.library,INT_REV)
```

where

intuition.library is the name of the particular library that the function is opening.

INT_REV is the current revision number of the library.

OpenLibrary() returns the address of the loaded module or NULL if the load has failed. Since this function is used to open other libraries—the graphics one, for example—we must cast it to the correct pointer type. This bit of code must be a part of any program that uses Intuition.

Windows and Screens

The *window* is the basic element in an Intuition display. It is not the most elementary—the screen underlies and contains all windows—but it is the one in which all of the action takes place.

A window, at its simplest, is a rectangular box that can be placed anywhere on the screen. This is the minimum window, not allowing for any output text or graphics. Of course you can do much more with a window. You draw pictures in it, send messages through it, and take input with it. It serves multitasking by allowing each running program to have a kind of virtual terminal of its own to work through. Thus, you can keep track of more than

one process at a time, although only one window can be active for input at any given moment. Moreover, each process has sole control of its console device, so no special consideration need be given to coordinating the output of disparate programs. Because of their importance, the creation and manipulation of windows within Intuition is an optimized procedure.

A *screen* is a somewhat more limited structure. It is the background upon which windows are displayed and manipulated. Like the window, the screen shows a rectangular figure on the display. This does not mean that a screen definition is only a specification for a background display—a few colors and maybe a style of lettering. The screen contains the window not only in the sense of framing its display, but in the more profound sense of containing all of the structures and values that the window itself manipulates. It is both a tangible limit and a system work area for the windows.

There are two kinds of screens available under Intuition. The standard is the *Workbench Screen*; this is predefined and needs no specification or action on the part of an application to open or close. But Intuition also allows the option of creating a *customized screen* specialized to a particular program or set of programs. In the latter case, the screen must be specified; its values must be initialized; and it must be explicitly opened before any windows can make use of its capabilities. The Workbench Screen is the one you are already familiar with: it covers the entire display area and contains the familiar capabilities. A customized screen can be any size, within the limits set by Intuition, and can contain either a subset or superset of the features found in the Workbench Screen. The chief advantage of the Workbench Screen is that it offers a standard interface to the user—one that is the same over a variety of applications. Also, it runs in concert with the Workbench application and has available to it specialized characteristics, such as icons, which may not be easy to import to a customized screen. Figure 3-1 shows a typical Workbench Screen; Figure 3-2, a customized one.

A screen allocation not only creates the display that you see, but also sets aside a workspace within memory where you can define your windows. Each window requires not only a set of data objects to manage its changing values, but also space to perform its calculations and an area to draw any necessary graphics. In addition to this, the screen sets certain parameters that are inherited by its windows. For example, the screen sets the color registers and the default type font.

Even though a screen is a basic element in an Intuition display, there is not a single basic screen underlying all others. There can be as many screens running as is desired and can be supported by the memory resouces of the system. Each screen is a world unto itself, as there can be no direct communication between them or between their windows. Windows cannot be moved outside of their designated screens. However, screens may overlay one another either wholly or partially.

In this chapter you will first explore the definition and manipulation of windows and screens. You will discover not only how to make them appear, but also how to manipulate their interrelationship to produce displays and applications.

Figure 3-1. Workbench Screen

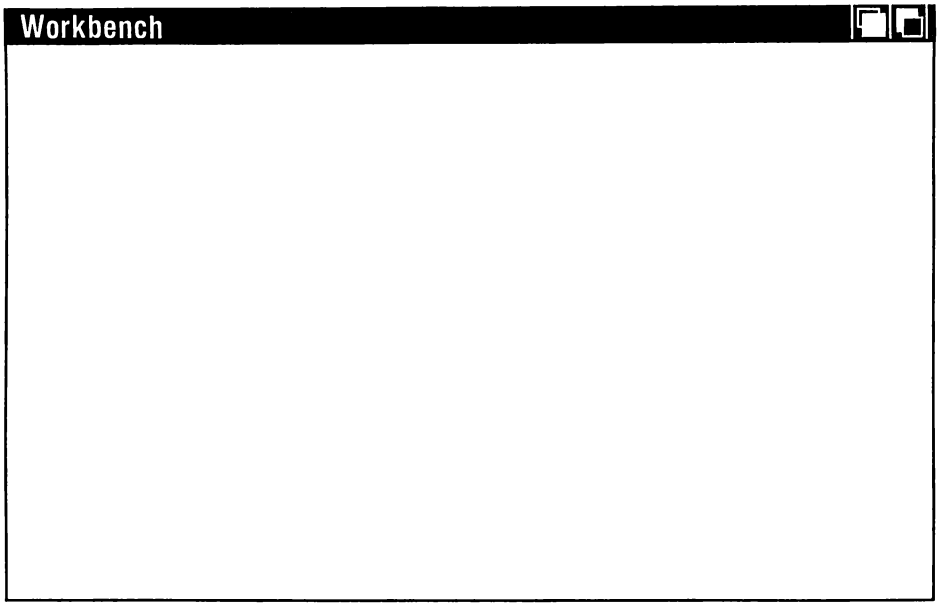
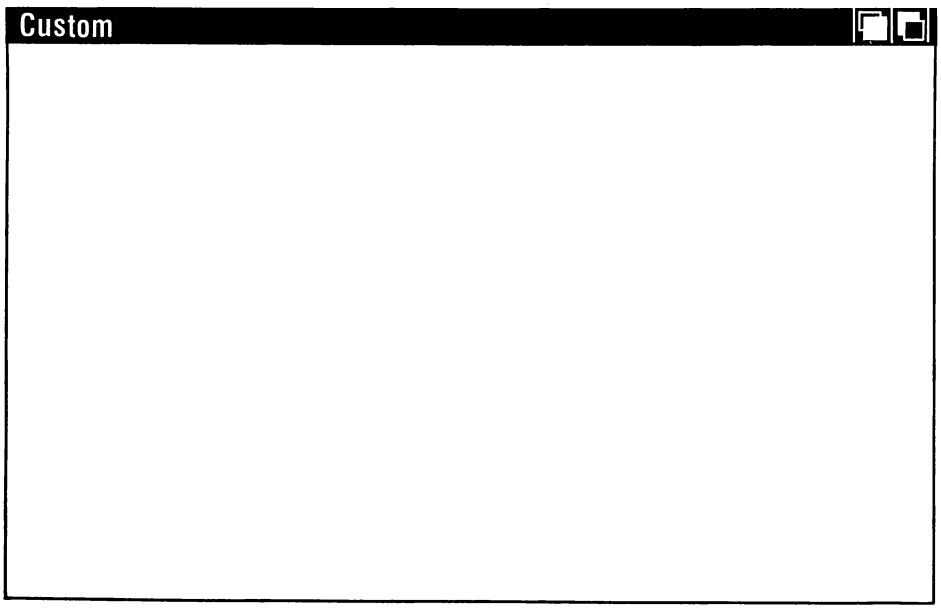


Figure 3-2. User-customized screen



Defining a Window

Let us begin by defining some simple windows in the Workbench Screen. A great deal of programming is done within this environment, and it will allow

you to focus on window-specific topics and put aside, for the moment, some of the complications generated by customized screens. Additionally, it will provide some interesting objects that you can then reimplement in custom screens, to explore these complications more fully.

Two objects are necessary to create a window. These objects are specified by a C structure. The *NewWindow* structure is used to specify the parameters of a window and pass those values to the Intuition function, *OpenWindow()*, which creates the window. This function initializes the second structure associated with an open window, the *window* structure; this, in turn, is used to manipulate the window.

NewWindow is a temporary structure that is only needed until the window is up and running. Its memory can then be deallocated or reused to open another window. NewWindow is a C structure with the following form:

```
struct NewWindow {
     SHORT LeftEdge,TopEdge,
           Width,Height;
     UBYTE DetailPen,BlockPen;
     USHORT IDCMPFlags;
     ULONG Flags;
     struct Gadget *FirstGadget;
     struct Image *CheckMark;
     UBYTE *Title;
     struct Screen *Screen;
     struct BitMap *BitMap;
     SHORT MinWidth,MinHeight,
           MaxWidth,MaxHeight;
     USHORT Type;
};
```

Each one of these fields controls one or more aspects of the window, but we will initially restrict ourselves to the minimal subset necessary to display a window.

LeftEdge and **TopEdge** define the coordinates of the upper left hand corner of the window, setting its initial position.

Width and **Height** set the size of the displayed window.

DetailPen and **BlockPen** contain references to the colors used to draw around and within the window;

Flags contains a series of values that set various capabilities and activities.

Text is the title of the window.

Type refers to the screen in which the window will be embedded.

For now, we will set the other fields to NULL or 0 and ignore them. The values assigned to these fields are partially dependent on the characteristics of the screen and partially on your own desire.

The initial position of the window is set in relation to the upper left-hand corner of the enclosing screen. This is always position 0,0. The units of these measurements are *pixels* or picture elements, but the size of these pixels is

dependent on the resolution of the display—a screen parameter. Since initially we will be using the Workbench Screen, the resolution will be 640 horizontally by 200 vertically. Later on, when you experiment with custom screens, resolution is one of the parameters you can vary. Positioning of the window is in relation to its upper left-hand corner; so you can easily calculate where on the screen to position it, once you also decide on its *Width* and *Height*. These are also set in terms of pixels and may vary with the resolution of the underlying screen.

The other fields are straightforward. The *Title* is a character string that contains the contents of the title bar, which will appear at the top of the window. The screen type is Workbench, so the *Type* field will be set to WBENCHSCREEN. Both *DetailPen* and *BlockPen* are set to color register numbers. These are the colors that will be used to draw the window. *DetailPen* sets the color that will be used to draw the borders and the details of the window, while *BlockPen* indicates the color that will be used for the block in the window. If these fields are initialized to −1, the screen defaults will be used. The *Flags* field is one of the most important in the structure. We will use the ACTIVATE flag, which will cause the window to become active as soon as it is opened. This means that it will be the one waiting to receive input.

Listing 3-1 shows a program that will open a simple window in the Workbench Screen. You will see right away how strange this minimal display looks next to the application screens that you are used to seeing in Amiga applications. Nearly everything about the window is controlled by a variable; this is to give maximum flexibility to the programmer. Gradually we will increase the complexity of our sample windows, by filling in these other fields. By the time we discuss graphics in Chapter 5, we will have explored the full power of Intuition's window system. In this example, we declare a variable window as a pointer to a window structure. We open the Intuition library, then the window, and finally close it. The most interesting action takes place in the function *make_window()*. We declare a variable *NewWindow* of type struct *NewWindow* in the function; this is an automatic variable that will disappear when the function returns to *main()*. This will not be a problem, because these values are only needed for a call to *OpenWindow()*; once this is done, the structure can be discarded. We set the members of *NewWindow* to the values that we want for our window. In this case, it will be 300 pixels wide by 100 high and will be positioned at location 20,20 in the underlying screen. We also set the title and the colors. Many of the fields are set at defaults or common values. These will be explained later in the chapter.

Listing 3-1. The creation of a simple window in the Workbench Screen.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct IntuitionBase *IntuitionBase;
struct Window *Window;
```

Listing 3-1. (cont.)

```
#define INTUITION_REV 33


main()
{
 LONG i;

 OpenAll();

 /*   ======Open a new window=====  */

  make_window(); /*error checking could be included*

 /*   ======Delay for a bit to show off the window====== */

  for(i=0;i<1000000;i++)
    ;
  CloseWindow(Window);
}

OpenAll()
/*This function will open the necessary libraries */
{

 IntuitionBase=(struct IntuitionBase *)
            OpenLibrary("intuition.library",INTUITION_REV);

 if(IntuitionBase==NULL)
    exit(FALSE);
 }

make_window()
/* This function will initialize the NewWindow structure
   and open the window  */
{
  struct NewWindow NewWindow;

  NewWindow.LeftEdge=20;
  NewWindow.TopEdge=20;
  NewWindow.Width=300;
  NewWindow.Height=100;
  NewWindow.DetailPen=0;
  NewWindow.BlockPen=1;
  NewWindow.Title="A Simple Window";
  NewWindow.Flags=SMART_REFRESH|ACTIVATE|BORDERLESS;
  NewWindow.IDCMPFlags=NULL;
  NewWindow.Type=WBENCHSCREEN;
  NewWindow.FirstGadget=NULL;
  NewWindow.CheckMark=NULL;
  NewWindow.Screen=NULL;
  NewWindow.BitMap=NULL;
  NewWindow.MinWidth=0;
  NewWindow.MinHeight=0;
```

Listing 3-1. (cont.)

```
NewWindow.MaxWidth=0;
NewWindow.MaxHeight=0;


Window=(struct Window *) OpenWindow(&NewWindow);

if(Window==NULL)
  exit(FALSE);
```

The call to *OpenWindow()* is the heart of this function. Note that this system routine takes a pointer to the NewWindow structure as a parameter. It returns the address of the window structure that will be associated with this open window; it allocates the memory for this structure; and it initializes the values. If *OpenWindow()* fails, it returns a value of NULL and the program will exit.

Once the window has been successfully opened, *make_window()* returns control to *main()*. Here we set up a delay loop so that we may view our handiwork, and then we close the window. This closure is accomplished by a call to:

```
CloseWindow(Window)
```

Here *Window* is also a pointer to a currently open window. It is always important on a multiprocessing system such as the Amiga to be careful about relinquishing resources when finished with them. Failure to do this can lead to deadlock situations, where program execution comes to a halt, because memory or some necessary device is not available.

Certain key operations in this example should be noted; they will be true of all subsequent window examples. The basic steps necessary to open a window are:

- Declare a variable to represent the window. This must be a global variable of type struct *Window*.
- Declare and initialize a NewWindow structure.
- Call *OpenWindow* with the NewWindow structure as a parameter.
- Remember to close the window when it is no longer needed.

The complexity of the process is really a function of the fields set in NewWindow. For this example, we set up the minimum window. All of the fields were set with literal values. In a realistic program, some of these fields would be set with variable values.

The examples in this book, will explore a certain way of approaching particular kinds of programming problems. Intuition, in fact, poses several difficulties in relation to the kind of stylistic program designs that many more orthodox academic or technical programmers are accustomed to. The notion of windows and screens and their interaction with an operating system

that is more complex than average requires a unique technique. Intuition is extremely complex; it requires many variables and data structures even to perform the simplest of tasks. The programmer must evolve a way to deal with that complexity, or risk writing programs that are unmaintainable and undecipherable. What we have attempted to do in these examples is to depend heavily on defining C functions for the simple, basic operations and then to build the more complex operations out of these modular building blocks. Thus, our *make_window()* function hides the NewWindow structure from the main part of the program. If we were to eschew this technique and do everything in the main function—or any other function, for that matter—we would soon find ourselves with huge and completely unmanageable programs.

For the moment, ignore those fields in the NewWindow structure that have been set to the ubiquitous NULL, concentrating on those fields to which an explicit value has been given. The most important of these are: *LeftEdge*, *TopEdge*, *Width*, and *Height*. The first two locate the window on the display area. *TopEdge* specifies the window's vertical offset from the top and *LeftEdge* specifies its horizontal distance from the left-hand side. These two dictate where the window will initially appear when it comes into existence. Although a full discussion of them will come later in the chapter, these values are measured relative to the screen that encloses them. Most of the time, this means a measurement is taken from the top and sides of the display, but it is possible to define a screen that does not cover the entire area. The *Width* and *Height* indicate what size box appears.

DetailPen and *BlockPen* tell the machine which colors to apply in displaying the window. Depending on the resolution of the display—also a parameter that can be set through software—there are sixteen or thirty-two different colors available. *DetailPen* picks the color used to produce the figures and border lines in the window, while *BlockPen* addresses the area fills. In the simple example given earlier, we specified the same choices as the screen uses.

The *Title* field requires a character string. This string will appear in the title bar at the top of the window. In the example, we put a literal string in this place. In general, a variable would go here.

The *Type* field is used to indicate the kind of screen that will enclose the window. Currently, there are only two values possible for this field: WBENCHSCREEN and CUSTOMSCREEN. The former is used when using the standard Workbench Screen. The latter value is used to create an enclosing screen to custom specifications.

Most of the values talked about so far are intuitive. Things such as the title, size, and position of a window are all sensible parameters. The *Flags* field is a little different. This field is used to specify a miscellany of important values that will shape the display of the window. In the example, there are two such values: SMART_REFRESH and BORDERLESS. SMART_REFRESH specifies an activity that will make more sense to you after you learn about *system gadgets* (procedures that allow the user to interactively manipulate the window and screen). This value indicates to Intuition that it must take responsibility for redrawing the window if it is moved or otherwise altered. The BORDERLESS flag indicates a display option for the window. By default, windows are drawn as

a rectangle with a bar at the top and an outline drawn around the perimeter. This flag turns off that outline, although it still leaves the bar to display the title. The complete list of flag values is shown below.

ACTIVATE	Window will become active as soon as it is opened.
ACTIVEWINDOW	Enables the reporting mechanism that alerts program when its window is active.
BACKDROP	Creates a window that remains behind all other windows.
BORDERLESS	Specifies no borders when drawing the window.
INACTIVEWINDOW	Enables reporting on the Inactive condition.
NOCAREREFRESH	Indicates that the window need not be refreshed after a change.
REPORTMOUSE	Enables the mechanism to report on mouse movements.
SIMPLE_REFRESH	Indicates that window redraw is the responsibility of the application.
SMART_REFRESH	Indicates that window redraw and reformat is done automatically.
SUPER_BITMAP	Specifies that window will have a separately maintained bit map.

Before continuing let's review what we have covered about creating a simple window. A window must have the following information specified:

- Its location within the screen or display
- Its display parameters: size and colors
- The kind of screen in which it is to be displayed
- Special instructions to the display system, such as the fact that the window is to be borderless

These values are common to all windows. Listing 3-2 shows another window definition similar to the initial example. This program also sets the minimal values needed to bring a window to visibility.

Listing 3-2. The creation of overlapping windows in the Workbench Screen.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct IntuitionBase *IntuitionBase;
struct Window *Wind0,*Wind1,*Wind2;

#define INTUITION_REV 33
```

Listing 3-2. (cont.)

```
main()
{
 SHORT x,y;
 UBYTE name[20];
 VOID delay_func();
 /*   ======Open Intuition======= */

 IntuitionBase=(struct IntuitionBase *)
           OpenLibrary("intuition.library",INTUITION_REV);

 if(IntuitionBase==NULL)
    exit(FALSE);

 /*   ======Open some windows=====  */

  strcpy(name,"Window 0");
  x=y=20;
  Wind0=(struct Window *)make_window(x,y,name);

  strcpy(name,"Window 1");
  x=y=40;
  Wind1=(struct Window *)make_window(x,y,name);

  strcpy(name,"Window 2");
  x=y=60;
  Wind2=(struct Window *)make_window(x,y,name);

 /*   ======Delay for a bit to show off the Windows====== */

  delay_func(1);

 /* =========Close down the windows in order========*/

  CloseWindow(Wind2);

  delay_func(1);

  CloseWindow(Wind1);

  delay_func(1);

  CloseWindow(Wind0);
}


make_window(x,y,name)
SHORT x,y;
UBYTE *name;
/* This function will initialize the NewWindow structure
   and open the window. Add error checking  */
{
  struct NewWindow NewWindow;
```

Listing 3-2. (cont.)

```
  NewWindow.LeftEdge=x;
  NewWindow.TopEdge=y;
  NewWindow.Width=300;
  NewWindow.Height=100;
  NewWindow.DetailPen=-1;
  NewWindow.BlockPen=-1;
  NewWindow.Title=name;
  NewWindow.Flags=ACTIVATE;
  NewWindow.IDCMPFlags=NULL;
  NewWindow.Type=WBENCHSCREEN;
  NewWindow.FirstGadget=NULL;
  NewWindow.CheckMark=NULL;
  NewWindow.Screen=NULL;
  NewWindow.BitMap=NULL;
  NewWindow.MinWidth=0;
  NewWindow.MinHeight=0;
  NewWindow.MaxWidth=0;
  NewWindow.MaxHeight=0;


  return(OpenWindow(&NewWindow));

}

VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000000;loop++)
   ;

 return;
}
```

Two new things should be noted about Listing 3-2. Most importantly, it opens more than a single window. In fact, it opens three: Wind0, Wind1, and Wind2. Each one of these must be represented by a window structure, and each one must be created by a separate call to *OpenWindow()*. They can, of course, share the same NewWindow structure, since it is only used during the setup process. Creating multiple windows like this is a common occurrence. Note how Intuition automatically takes care of the display problems involved with overlapping windows. Also in this example, there are two new values used in the NewWindow structure. *DetailPen* and *BlockPen* are set to −1. This value indicates to Intuition that the screen default values are also to be used for the window. We've used the Flag value ACTIVATE to insure that the window will become active as soon as it is opened. The lack of a BORDERLESS value for this field results in the appearance of the windows neatly delineated by a clean, white border.

Listing 3-3 shows one of the uses of a borderless window: it can serve as a backdrop for the activity of other windows. In this program, we first open a window specifying the BORDERLESS flag and covering the entire display area—640 by 200. Once this underlying window is in place, we open three ordinary windows that appear in front of it. This is a useful technique for creating a clean and pleasant display. It will be used to good effect during graphics programming in Chapter 5.

Listing 3-3. Creation of overlapping windows in the Workbench Screen with a borderless window in the background.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct IntuitionBase *IntuitionBase;
struct Window *Wind0,*Wind1,*Wind2,*NoBorder;

#define INTUITION_REV 33


main()
{
 ULONG flags;
 SHORT x,y,w,h;
 UBYTE name[60];
 VOID delay_func();
 /*   ======Open Intuition======= */

 IntuitionBase=(struct IntuitionBase *)
           OpenLibrary("intuition.library",INTUITION_REV);

 if(IntuitionBase==NULL)
    exit(FALSE);

  /*  ======Open a borderless window======*/

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|BORDERLESS;
  NoBorder=(struct Window *)make_window(x,y,w,h,NULL,flags);


 /*   ======Open some plain windows=====  */

  strcpy(name,"Window 0");
  x=y=20;
  w=300;
  h=100;
  flags=ACTIVATE;
  Wind0=(struct Window *)make_window(x,y,w,h,name,flags);

  strcpy(name,"Window 1");
  x=y=40;
```

Listing 3-3. (cont.)

```
  Wind1=(struct Window *)make_window(x,y,w,h,name,flags);

  strcpy(name,"Window 2");
  x=y=60;
  Wind2=(struct Window *)make_window(x,y,w,h,name,flags);

 /*   ======Delay for a bit to show off the windows====== */

  delay_func(100);

 /* =========Close down the windows in order========*/

  CloseWindow(Wind2);

  delay_func(10);

  CloseWindow(Wind1);

  delay_func(10);

  CloseWindow(Wind0);

  delay_func(10);

  CloseWindow(NoBorder);
}


make_window(x,y,w,h,name,flags)
SHORT x,y,w,h;
UBYTE *name;
ULONG flags;
/* This function will initialize the NewWindow structure
   and open the window. Error checking should be added */
{
  struct NewWindow NewWindow;

  NewWindow.LeftEdge=x;
  NewWindow.TopEdge=y;
  NewWindow.Width=w;
  NewWindow.Height=h;
  NewWindow.DetailPen=-1;
  NewWindow.BlockPen=-1;
  NewWindow.Title=name;
  NewWindow.Flags=flags;
  NewWindow.IDCMPFlags=NULL;
  NewWindow.Type=WBENCHSCREEN;
  NewWindow.FirstGadget=NULL;
  NewWindow.CheckMark=NULL;
  NewWindow.Screen=NULL;
  NewWindow.BitMap=NULL;
  NewWindow.MinWidth=0;
  NewWindow.MinHeight=0;
  NewWindow.MaxWidth=0;
```

Listing 3-3. (cont.)

```
  NewWindow.MaxHeight=0;


  return(OpenWindow(&NewWindow));

}

VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Listing 3-4 shows a variation of the previous examples. The situation is the same, but each window in the foreground of the display is a different color. This is accomplished by specifying a different color register for the two color members in the NewWindow structure: *DetailPen* and *BlockPen*. The number of colors available is a function of the screen. In the case of the Workbench Screen, there are four.

Listing 3-4. Creation of overlapping windows in the Workbench Screen, with a borderless window in the background. In this program, we specify different colors for the small windows.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct IntuitionBase *IntuitionBase;
struct Window *Wind0,*Wind1,*Wind2,*NoBorder;

#define INTUITION_REV 33


main()
{
 ULONG flags;
 SHORT x,y,w,h;
 UBYTE *name,c0,c1;
 VOID delay_func();

 /*   ======Open Intuition======= */

 IntuitionBase=(struct IntuitionBase *)
           OpenLibrary("intuition.library",INTUITION_REV);
```

Listing 3-4. (cont.)

```
if(IntuitionBase==NULL)
   exit(FALSE);

 /*  ======Open a borderless window======*/

 x=y=0;
 w=640;
 h=200;
 c0=c1=-0x01;
 flags=ACTIVATE|BORDERLESS;
 NoBorder=(struct Window *)
    make_window(x,y,w,h,NULL,flags,c0,c1);

/*   ======Open some plain windows=====  */

 name="Window 0";
 x=y=20;
 w=300;
 h=100;
 flags=ACTIVATE;
 c0=0x10;
 c1=0x15;

 Wind0=(struct Window *)make_window(x,y,w,h,name,flags,c0,c1);

 name="Window 1";
 x=y=40;
 c0=0x17;
 c1=0x19;

 Wind1=(struct Window *)make_window(x,y,w,h,name,flags,c0,c1);

 name="Window 2";
 x=y=60;
 c0=0x00;
 c1=0x1a;

 Wind2=(struct Window *)make_window(x,y,w,h,name,flags,c0,c1);

/*   ======Delay for a bit to show off the windows====== */

 delay_func(100);

/* =========Close down the windows in order========*/

 CloseWindow(Wind2);

 delay_func(10);

 CloseWindow(Wind1);

 delay_func(10);
```

Listing 3-4. (cont.)

```
  CloseWindow(Wind0);

  delay_func(10);

  CloseWindow(NoBorder);
}


make_window(x,y,w,h,name,flags,color0,color1)
SHORT x,y,w,h;
UBYTE *name,color0,color1;
ULONG flags;
/* This function will initialize the NewWindow structure
   and open the window. Error checking should be added  */
{
  struct NewWindow NewWindow;

  NewWindow.LeftEdge=x;
  NewWindow.TopEdge=y;
  NewWindow.Width=w;
  NewWindow.Height=h;
  NewWindow.DetailPen=color0;
  NewWindow.BlockPen=color1;
  NewWindow.Title=name;
  NewWindow.Flags=flags;
  NewWindow.IDCMPFlags=NULL;
  NewWindow.Type=WBENCHSCREEN;
  NewWindow.FirstGadget=NULL;
  NewWindow.CheckMark=NULL;
  NewWindow.Screen=NULL;
  NewWindow.BitMap=NULL;
  NewWindow.MinWidth=0;
  NewWindow.MinHeight=0;
  NewWindow.MaxWidth=0;
  NewWindow.MaxHeight=0;


  return(OpenWindow(&NewWindow));

}

VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

So far, all we have done with windows is to display them. But windows are the true workhorses of Intuition. Windows can move, change in size, show graphics displays and text, and can take input. But before we go on to explore these topics, we must turn our attention to the object that encloses windows—the screen.

Customizing Screens

Although windows are more versatile than screens and easier to control, there is a great deal of power and flexibility packed into the screen definitions. Customized screens combined with windows allow the programmer to create any user interface that may be desired.

A screen is defined in a way analogous to the window. There is a *NewScreen* structure that allows the specification of screen parameters. This takes the form:

```
struct NewScreen {
     SHORT LeftEdge,TopEdge,
           Height,Depth;
     UBYTE DetailPen,BlockPen;
     USHORT ViewModes,
            Type:
     struct TextAttr *Font;
     UBYTE *DefaultTitle;
     struct Gadgets *Gadgets;
     struct BitMap *CustomBitMap;
};
```

These fields are filled out with appropriate values, and a pointer to the structure is passed to the Intuition function *OpenScreen()*. This, in turn, returns the address of a screen structure which can be used in subsequent interactions. A call to *CloseScreen()* removes it from the display.

Listing 3-5 illustrates the display of a simple window within a customized screen. The NewScreen structure is smaller than NewWindow, and almost all of its fields are critical and need to be initialized. Only *Font, Gadgets*, and *CustomBitMap* are optional and set to NULL. The creation of this new screen has been exported to a function, *make_screen()*. As with NewWindow, NewScreen need exist only long enough to serve as a parameter for *OpenScreen()*. This function will return a pointer to a screen structure associated with the now open and resident screen. If the call fails, NULL will be returned and the example program will exit. The function *make_screen()* returns this pointer value. Note that we must cast this value to a pointer to type struct *Screen* back in *main()*.

Listing 3-5. Creation of a window in a custom screen.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct IntuitionBase *IntuitionBase;
```

Listing 3-5. (cont.)

```
struct Window *Window;
struct Screen *Screen;

#define INTUITION_REV 33


main()
{
 ULONG flags;
 SHORT x,y,w,h,d;
 USHORT mode;
 UBYTE *name,c0,c1;
 VOID delay_func();

 /*   ======Open Intuition======= */

 IntuitionBase=(struct IntuitionBase *)
           OpenLibrary("intuition.library",INTUITION_REV);

 if(IntuitionBase==NULL)
    exit(FALSE);
 /*  ======Open a custom screen==== */

  name="Screen";
  y=0;
  w=320;
  h=200;
  d=5;
  c0=0x00;
  c1=0x01;
  mode=NULL;

  Screen=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,name);

 /*   ======Open windows=====  */

  name="Window";
  x=y=20;
  w=100;
  h=100;
  flags=ACTIVATE;
  c0=-0x01;
  c1=-0x01;

  Window=(struct Window *)
           make_window(x,y,w,h,name,flags,c0,c1,Screen);

 /*   ======Delay for a bit to show off the windows====== */

  delay_func(100);

 /* =========Close down the window then the screen========*/
```

Listing 3-5. (cont.)

```
  CloseWindow(Window);


  delay_func(10);

  CloseScreen(Screen);

}


make_window(x,y,w,h,name,flags,color0,color1,screen)
SHORT x,y,w,h;
UBYTE *name,color0,color1;
ULONG flags;
struct Screen *screen;
/* This function will initialize the NewWindow structure
   and open the window. Error checking should be added  */
{
  struct NewWindow NewWindow;

  NewWindow.LeftEdge=x;
  NewWindow.TopEdge=y;
  NewWindow.Width=w;
  NewWindow.Height=h;
  NewWindow.DetailPen=color0;
  NewWindow.BlockPen=color1;
  NewWindow.Title=name;
  NewWindow.Flags=flags;
  NewWindow.IDCMPFlags=NULL;
  NewWindow.Type=CUSTOMSCREEN;
  NewWindow.FirstGadget=NULL;
  NewWindow.CheckMark=NULL;
  NewWindow.Screen=screen;
  NewWindow.BitMap=NULL;
  NewWindow.MinWidth=0;
  NewWindow.MinHeight=0;
  NewWindow.MaxWidth=0;
  NewWindow.MaxHeight=0;


  return(OpenWindow(&NewWindow));

}

make_screen(y,w,h,d,color0,color1,mode,name)
SHORT y,w,h,d;
UBYTE color0,color1,*name;
USHORT mode;
{
 struct NewScreen NewScreen;

 NewScreen.LeftEdge=0;
 NewScreen.TopEdge=y;
 NewScreen.Width=w;
```

Listing 3-5. (cont.)

```
 NewScreen.Height=h;
 NewScreen.Depth=d;
 NewScreen.DetailPen=color0;
 NewScreen.BlockPen=color1;
 NewScreen.ViewModes=mode;
 NewScreen.Type=CUSTOMSCREEN;
 NewScreen.Font=NULL;
 NewScreen.DefaultTitle=name;
 NewScreen.Gadgets=NULL;
 NewScreen.CustomBitMap=NULL;

 return(OpenScreen(&NewScreen));
}

VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

LeftEdge and *TopEdge* are meant to set the position of the screen. A screen must take up the full width of the display area. The height can be set. The screen can be smaller than the display area. *TopEdge* indicates upon which of the 200 possible lines the top of the screen will start. There is a further qualification: if the screen is less than the full height of the display, it must occupy the lower half. A small screen always goes from its top to the last possible line on the video screen. *TopEdge* must be coordinated with the *Height* field. If the screen is specified as less than 200 lines high, then *TopEdge* cannot start at the 0,0 point. The example specifies a screen that covers the full display.

Even though a screen must be as wide as the display, the *Width* field has a use: it must be set to the number of pixels across the screen. In high-resolution mode, *Width* is set to 640, while low-resolution is only 320. This field is used in conjunction with the *ViewModes* field. *ViewModes* specifies the format of the screen display. For the most part, its values deal with display resolution.

HIRES	indicates a high-resolution screen (640 x 200).
INTERLACE	indicates 400 line interlace mode.
SPRITES	allows the use of these objects in the window.
HAM	indicates hold-and-modify mode.

In the example, we are defining a low-resolution screen and have set the fields accordingly.

The *Depth* field indicates the number of colors that will be available to the screen and its objects. Its value is the number of bit planes allocated for the screen. One bit plane will give only two colors; three bit planes will give eight colors. Up to five bit planes can be specified. A complete discussion of bit planes will be deferred until Chapter 5. Each pixel has a value in each plane, and these are combined to give a color register address. The color of an individual pixel is indirectly addressed by this mechanism. *DetailPen* and *BlockPen* contain the specific color registers to be used for these functions. *Type* must be set to CUSTOMSCREEN. *DefaultTitle* points to a character string that contains the name that will appear in the screen's title bar.

One reason why screen definitions are so important is that the objects contained within screens inherit these characteristics. For example, the window created by the example is low-resolution, just as the screen is, and uses the same default colors. This consistency is absolute. There is no way a high-resolution window can be defined in a low-resolution screen.

Listing 3-6. Creation of a window in a custom screen. This time, we have altered the default colors.

```
/*  ======Open a custom screen==== */

 name="Screen";
 y=0;
 w=320;
 h=200;
 d=5;
 c0=0x10;
 c1=0x11;
 mode=NULL;

 Screen=(struct Screen *)
        make_screen(y,w,h,d,c0,c1,mode,name);

/*   ======Open windows=====  */

 name="Window";
 x=y=20;
 w=100;
 h=100;
 flags=ACTIVATE;
 c0=-0x01;
 c1=-0x01;

 Window=(struct Window *)
         make_window(x,y,w,h,name,flags,c0,c1,Screen);
```

Listing 3-6 shows a slight modification to the last example. Here we've altered the default colors but otherwise the program is identical to Listing 3-5. Listing 3-7 shows a somewhat more interesting variation. Here we open

two overlapping screens, each with its own window. Note that we have switched to high-resolution mode. Because of this, we adjusted the *Width* field accordingly and set *ViewModes* to the flag HIRES. Screen 1 is shorter than Screen 2. Listing 3-8 shows the same two screens, but this time the smaller one is in low-resolution mode. Although all objects within a screen must share its resolution, nothing prevents us from mixing screens of different resolutions on the same display.

Listing 3-7. Creation of two overlapping custom screens, each with a window.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct IntuitionBase *IntuitionBase;
struct Window *wind0,*wind1;
struct Screen *Scrn0,*Scrn1;

#define INTUITION_REV 33


main()
{
 ULONG flags;
 SHORT x,y,w,h,d;
 USHORT mode;
 UBYTE *name,c0,c1;
 VOID delay_func();

 /*   ======Open Intuition======= */

 IntuitionBase=(struct IntuitionBase *)
           OpenLibrary("intuition.library",INTUITION_REV);

 if(IntuitionBase==NULL)
    exit(FALSE);

 /*  ======Open a hi-res custom screen==== */

  name="Screen 0";
  y=0;
  w=640;
  h=200;
  d=3;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn0=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,name); /* Add error checking */

 /*  =======And a window==============*/
```

Listing 3-7. (cont.)

```
 name="Window 0";
 x=20;
 y=20;
 w=300;
 h=100;
 flags=ACTIVATE;
 c0=-0x01;
 c1=-0x01;

 wind0=(struct Window *)
          make_window(x,y,w,h,name,flags,c0,c1,Scrn0); /* Add error
                      checking */


/*  ======Open another hi-res custom screen==== */

 name="Screen 1";
 y=50;
 w=640;
 h=150;
 d=3;
 c0=0x00;
 c1=0x01;
 mode=HIRES;

 Scrn1=(struct Screen *)
         make_screen(y,w,h,d,c0,c1,mode,name); /* Add error checking */

/*  =======And a window==============*/

 name="Window 1";
 x=20;
 y=20;
 w=300;
 h=100;
 flags=ACTIVATE;
 c0=-0x01;
 c1=-0x01;

 wind1=(struct Window *)
          make_window(x,y,w,h,name,flags,c0,c1,Scrn1); /* Add error
                      checking */

/*   ======Delay for a bit to show off the window====== */

 delay_func(100);

/* =========Close down the window then the screen========*/

 CloseWindow(wind1);

 CloseScreen(Scrn1);
```

Listing 3-7. (cont.)

```
  delay_func(10);

  CloseWindow(wind0);

  CloseScreen(Scrn0);
}


make_window(x,y,w,h,name,flags,color0,color1,screen)
SHORT x,y,w,h;
UBYTE *name,color0,color1;
ULONG flags;
struct Screen *screen;
/* This function will initialize the NewWindow structure
   and open the window. Error checking should be added */
{
  struct NewWindow NewWindow;

  NewWindow.LeftEdge=x;
  NewWindow.TopEdge=y;
  NewWindow.Width=w;
  NewWindow.Height=h;
  NewWindow.DetailPen=color0;
  NewWindow.BlockPen=color1;
  NewWindow.Title=name;
  NewWindow.Flags=flags;
  NewWindow.IDCMPFlags=NULL;
  NewWindow.Type=CUSTOMSCREEN;
  NewWindow.FirstGadget=NULL;
  NewWindow.CheckMark=NULL;
  NewWindow.Screen=screen;
  NewWindow.BitMap=NULL;
  NewWindow.MinWidth=0;
  NewWindow.MinHeight=0;
  NewWindow.MaxWidth=0;
  NewWindow.MaxHeight=0;


  return(OpenWindow(&NewWindow));

}

make_screen(y,w,h,d,color0,color1,mode,name)
SHORT y,w,h,d;
UBYTE color0,color1,*name;
USHORT mode;
{
 struct NewScreen NewScreen;

 NewScreen.LeftEdge=0;
 NewScreen.TopEdge=y;
 NewScreen.Width=w;
```

Listing 3-7. (cont.)

```
 NewScreen.Height=h;
 NewScreen.Depth=d;
 NewScreen.DetailPen=color0;
 NewScreen.BlockPen=color1;
 NewScreen.ViewModes=mode;
 NewScreen.Type=CUSTOMSCREEN;
 NewScreen.Font=NULL;
 NewScreen.DefaultTitle=name;
 NewScreen.Gadgets=NULL;
 NewScreen.CustomBitMap=NULL;

 return(OpenScreen(&NewScreen)); /* Add error checking */
}

VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Listing 3-8. Creation of two overlapping custom screens, each with a window. One of the screens is high-resolution, the other is low-resolution.

```
/*  ======Open a low-res custom screen==== */

  name="Low Resolution Screen";
  y=50;
  w=320;
  h=150;
  d=3;
  c0=0x00;
  c1=0x01;
  mode=NULL;

  Scrn1=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,name);

/*  =======And a window==============*/

  name="Window";
  x=20;
  y=20;
```

Listing 3-8. (cont.)

```
w=150;
h=100;
flags=ACTIVATE;
c0=-0x01;
c1=-0x01;

wind1=(struct Window *)
        make_window(x,y,w,h,name,flags,c0,c1,Scrn1);
```

Intuition supports an additional very-high-resolution mode. You can create a screen in interlaced mode that gives 400 vertical lines instead of the 200 offered by normal high-resolution. In normal high-resolution, the 200 lines of vertical movement are laid out in one cycle (Figure 3-3). In interlaced mode it takes two screen cycles to complete the picture. First one set of 200 lines is drawn on the screen. Then the hardware moves to the top and draws a second set of 200 lines, slightly offset from its first action. In two cycles 400 lines are drawn (Figure 3-4). Listing 3-9 illustrates a program that will put up a high-resolution interlaced screen and window. The *Height* field has been initialized to 400 and *ViewMode* is the bitwise OR of both the HIRES and the INTERLACE flags. The interlaced screen can produce a distracting flicker on the display; this is a problem that may be solved by using a monitor with a high-persistence phosphor.

Figure 3-3. Drawing in normal resolution

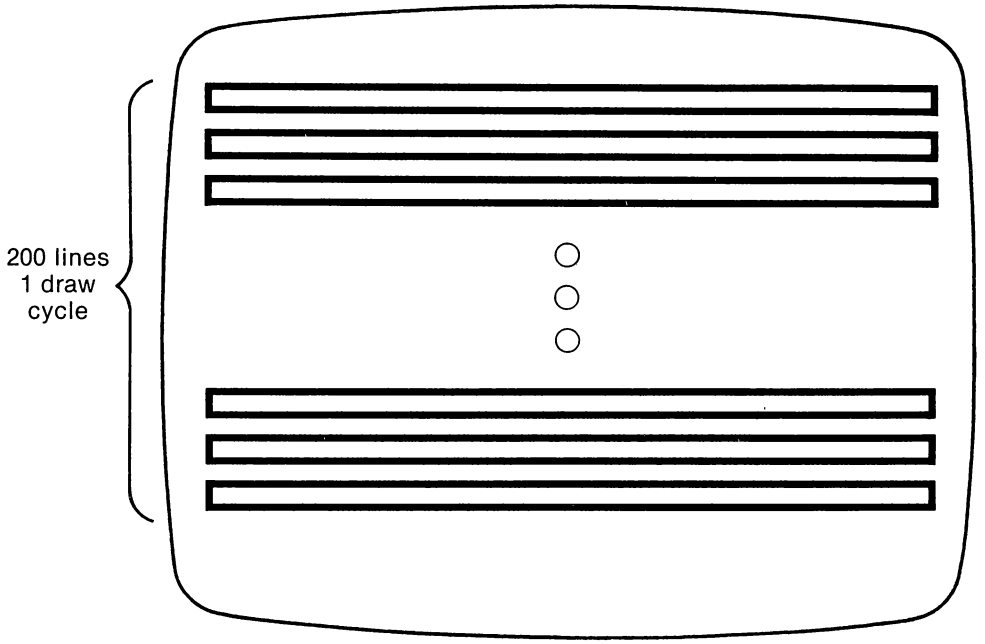
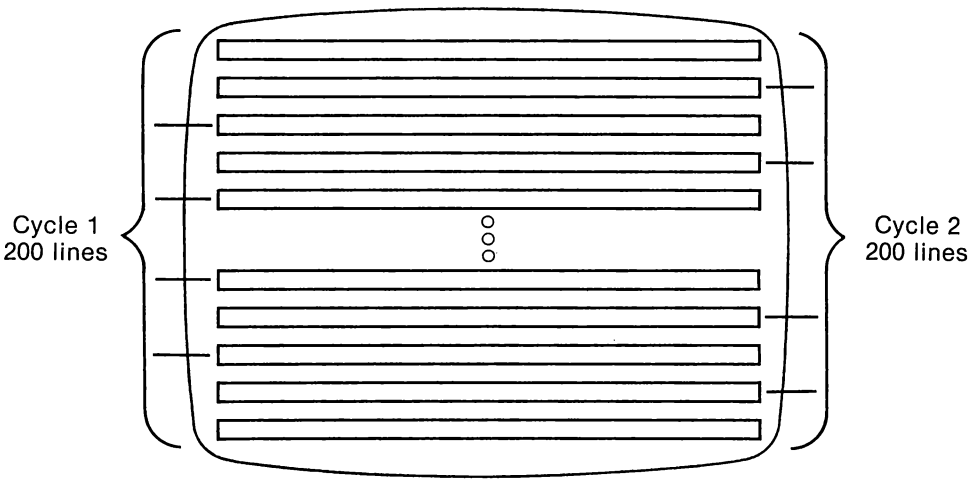


Figure 3-4. Drawing in interlace mode



Listing 3-9. Creation of a high-resolution interlaced screen and window.

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/display.h>

struct IntuitionBase *IntuitionBase;
struct Window *wind;
struct Screen *Scrn;

#define INTUITION_REV 33


main()

{
 ULONG flags;
 SHORT x,y,w,h,d;
 USHORT mode;
 UBYTE *name,c0,c1;
 VOID delay_func();

 /*   ======Open Intuition======= */

 IntuitionBase=(struct IntuitionBase *)
           OpenLibrary("intuition.library",INTUITION_REV);

 if(IntuitionBase==NULL)
    exit(FALSE);
```

Listing 3-9. (cont.)

```
 /*  ======Open a hi-res custom screen==== */

  name="High Resolution Screen";
  y=0;
  w=640;
  h=400;
  d=3;
  c0=0x00;
  c1=0x01;
  mode=HIRES|INTERLACE;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,name); /* error check */

 /*  =======And a window==============*/

  name="Window";
  x=20;
  y=20;
  w=300;
  h=100;
  flags=ACTIVATE;
  c0=-0x01;
  c1=-0x01;

  wind=(struct Window *)
           make_window(x,y,w,h,name,flags,c0,c1,Scrn); /* error check */

 /*   ======Delay for a bit to show off the window====== */

  delay_func(100);

 /* =========Close down the window then the screen========*/

  CloseWindow(wind);

  CloseScreen(Scrn);

}


make_window(x,y,w,h,name,flags,color0,color1,screen)
SHORT x,y,w,h;
UBYTE *name,color0,color1;
ULONG flags;
struct Screen *screen;
/* This function will initialize the NewWindow structure
   and open the window  */
{
  struct NewWindow NewWindow;

  NewWindow.LeftEdge=x;
```

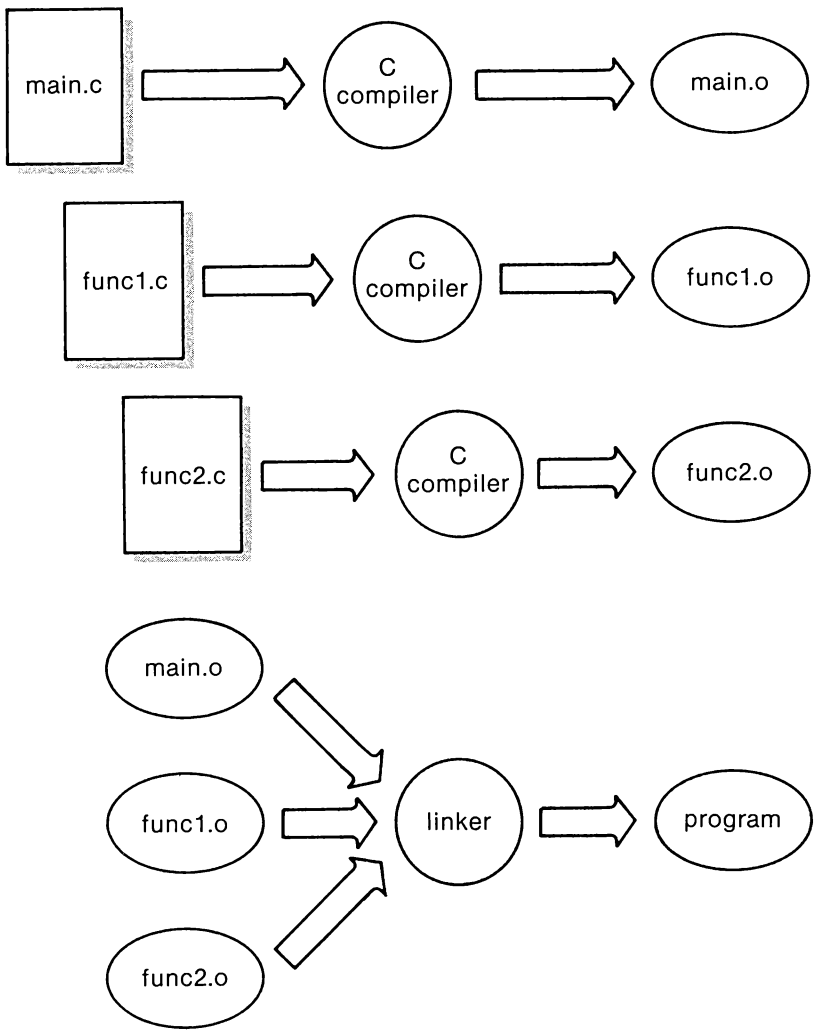
Listing 3-9. (cont.)

```
  NewWindow.TopEdge=y;
  NewWindow.Width=w;
  NewWindow.Height=h;
  NewWindow.DetailPen=color0;
  NewWindow.BlockPen=color1;
  NewWindow.Title=name;
  NewWindow.Flags=flags;
  NewWindow.IDCMPFlags=NULL;
  NewWindow.Type=CUSTOMSCREEN;
  NewWindow.FirstGadget=NULL;
  NewWindow.CheckMark=NULL;
  NewWindow.Screen=screen;
  NewWindow.BitMap=NULL;
  NewWindow.MinWidth=0;
  NewWindow.MinHeight=0;
  NewWindow.MaxWidth=0;
  NewWindow.MaxHeight=0;


  return(OpenWindow(&NewWindow));

}

make_screen(y,w,h,d,color0,color1,mode,name)
SHORT y,w,h,d;
UBYTE color0,color1,*name;
USHORT mode;
{
 struct NewScreen NewScreen;

 NewScreen.LeftEdge=0;
 NewScreen.TopEdge=y;
 NewScreen.Width=w;
 NewScreen.Height=h;
 NewScreen.Depth=d;
 NewScreen.DetailPen=color0;
 NewScreen.BlockPen=color1;
 NewScreen.ViewModes=mode;
 NewScreen.Type=CUSTOMSCREEN;
 NewScreen.Font=NULL;
 NewScreen.DefaultTitle=name;
 NewScreen.Gadgets=NULL;
 NewScreen.CustomBitMap=NULL;

 return(OpenScreen(&NewScreen));
}

VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;
```

Listing 3-9. (cont.)

```
 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Figure 3-5. Program modularization using separate files



Modular Programming

You may have noticed that our example programs are becoming unwieldy because of the complexity of Intuition. While we have made some small steps towards the management of this complexity—separate functions for opening windows and screens, for example—the C programming language allows us to go much further.

An executable C program is created in two stages: compilation and linking. Each step is independent of the other. It is possible to put individual functions into separate files, and then compile each file independently of the others. This separate compilation produces a file that is midway between the source code on the one hand and an executable program on the other. These files are incomplete and contain a mixture of executable code and references to routines outside of the current file. In addition, their addresses have to be reconciled. These object files can be combined by the linker to produce a program file. Figure 3-5 illustrates this process.

One important advantage of separate compilation is that we can separate functions that are common to many programs and place them into one or more files, compile these files, and just link the resulting object code with any program that might need those functions. For example, in every program that we have created so far, a call to OpenLibrary( ) is necessary to set up the Intuition environment. This operation along with its supporting declarations can be exported to a file. Listing 3-10 shows the contents of a file that will set up this environment.

Listing 3-10. A file to open Intuition.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct IntuitionBase *IntuitionBase;

#define INTUITION_REV 33        /* set the revision number of Intuition */

/* Open_All() sets up the intuition environment for the user. Error
              checking should be added*/

Open_All()
{
 IntuitionBase=(struct IntuitionBase *)
          OpenLibrary("intuition.library",INTUITION_REV);

 if(IntuitionBase==NULL)
  exit(FALSE);
}
```

This file is a semiautonomous unit containing declarations, references to standard include files, as well as a function that does the actual work. In this way, a collection of useful functions can be assembled which will serve many applications without the necessity of making them part of the application code itself. The code is, therefore, cleaner and easier to read.

Listing 3-11. The screen support function—S_sup.C.

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/display.h>

/*make_screen() will open a screen with the supplied characteristics.
                Add error checking*/

make_screen(y,w,h,d,color0,color1,mode,name)
SHORT y,w,h,d;
UBYTE color0,color1,*name;
USHORT mode;
{
 struct NewScreen NewScreen;

 NewScreen.LeftEdge=0;              /* initialize a NewScreen object */
 NewScreen.TopEdge=y;
 NewScreen.Width=w;
 NewScreen.Height=h;
 NewScreen.Depth=d;
 NewScreen.DetailPen=color0;
 NewScreen.BlockPen=color1;
 NewScreen.ViewModes=mode;
 NewScreen.Type=CUSTOMSCREEN;
 NewScreen.Font=NULL;
 NewScreen.DefaultTitle=name;
 NewScreen.Gadgets=NULL;
 NewScreen.CustomBitMap=NULL;

 return(OpenScreen(&NewScreen));    /* return the address of the screen */
}
```

We can create similar files to handle window and screen creation—two operations that are shared by nearly all Intuition programs. Listing 3-11 shows s_sup.c, a screen support function and Listing 3-12, w_sup.c, a function for windows. In both cases, the file may be independently compiled and linked into a program as needed, providing a necessary resource that can be called upon whenever these functions are needed in a program. In the examples which follow, we assume that the functions defined in these three files are available to the program being discussed, and we do not explicitly mention them.

Listing 3-12. The Window support function—w_sup.c.

```
#include <exec/types.h>
#include <intuition/intuition.h>

/* make_window() will open a window in the specified screen and with the
                indicated characteristics. More error checking is needed*/

make_window(x,y,w,h,name,flags,iflags,color0,color1,screen)
SHORT x,y,w,h;
UBYTE *name,color0,color1;
ULONG flags;
USHORT iflags;
struct Screen *screen;
{
  struct NewWindow xNewWindow;
  NewWindow.LeftEdge=x;             /* initialize a NewWindow object */
  NewWindow.TopEdge=y;
  NewWindow.Width=w;
  NewWindow.Height=h;
  NewWindow.DetailPen=color0;
  NewWindow.BlockPen=color1;
  NewWindow.Title=name;
  NewWindow.Flags=flags;
  NewWindow.IDCMPFlags=iflags;
  if(screen == NULL)
    NewWindow.Type=WBENCHSCREEN;
  else {
    NewWindow.Type=CUSTOMSCREEN;
    NewWindow.Screen=screen;
   }
  NewWindow.FirstGadget=NULL;
  NewWindow.CheckMark=NULL;
  NewWindow.Screen=screen;
  NewWindow.BitMap=NULL;
  NewWindow.MinWidth=0;
  NewWindow.MinHeight=0;
  NewWindow.MaxWidth=0;
  NewWindow.MaxHeight=0;

  return(OpenWindow(&NewWindow));   /* return the address of the window */

}
```

The exact format for compiling and linking these files varies according to the particular compiler/linker being used and may even vary from one version to the next. It's always wise to check the current manual. With the Lattice compiler and the alink linker the format is

```
--compiling...
        lc -iINCLUDE: prog.c
        lc -iINCLUDE: i_sup.c
        lc -iINCLUDE: s_sup.c
        lc -iINCLUDE: w_sup.c
```

where

lc is the driver program supplied with the compiler

prog.c is an application program

i_sup.c etc. are the various support files

INCLUDE: is the directory that contains the system header files

```
--linking...
        alink LIB:Lstartup.obj+prog.o+1_sup.o+s_sup.o+w_sup.o
        to prog LIB LIB:lc.lib+LIB:amiga.lib
```

where

alink is the linker

Lstartup.obj is the standard startup routine

lc.lib and **amiga.lib** are library files

prog.o, i_sup.o, etc. are object files

LIB: is the directory containing the standard libraries.

It must be noted that there are important variations and shortcuts for these command lines.

Gadgets

One of the most difficult tasks when using a window system such as Intuition is to set up channels of input and output. Each window and screen available to the user is a complex object with many changeable characteristics. It is not enough to send a few characters or a picture to a specific window. Things like its current position, size, and mode of activity must be known, as well as parameters such as font type and color. Getting values back from a window involves these problems as well as user interaction and movement around the display area. Intuition contains several subsystems that help to reduce the complexity of this problem. One of the most interesting of these is the gadget subsystem.

A *gadget* is a kind of "software machine." It is an input procedure set up to mimic some kind of physical control device. Frequently gadgets are displayed graphically to dramatically indicate their function. Other times they are rendered with text, but always with an eye to attracting the user's attention. The use of gadgets is linked to the mouse; even gadgets whose main function is to gather text frequently use the mouse to initiate a gadget session.

The "real world" orientation of these devices is underscored by the four types of gadgets that can be defined:

- Boolean gadgets ask a yes or no question; they return true or false.
- String gadgets look for a character string.

- Integer gadgets accept only a signed or unsigned string of digits.
- Proportional gadgets allow the user to specify a fraction or portion of a value.

The proportional type is the most flexible of all the gadget types. It offers a kind of input conversion that is difficult to accomplish: the translation of analog values into a form with which the computer can deal.

Gadgets are usually associated with windows, but they can also be attached to screens, outside of any particular window. This is another factor adding to their flexibility. When defined inside a window, they can be set up to share in any changes to that window. A difference in size or position will all be reflected in a proportionate change to the gadgets.

System Gadgets

Intuition offers four built-in gadgets that can be easily added to any window:

1. The Sizing Gadget allows the user to alter the size of a window dynamically.
2. The Depth Gadget adjusts the relative position of windows that overlay one another.
3. The Drag Gadget allows a window to be moved around the screen and then deposited at a new location.
4. The Close Gadget signals the owner of a window that the user wants to shut it down.

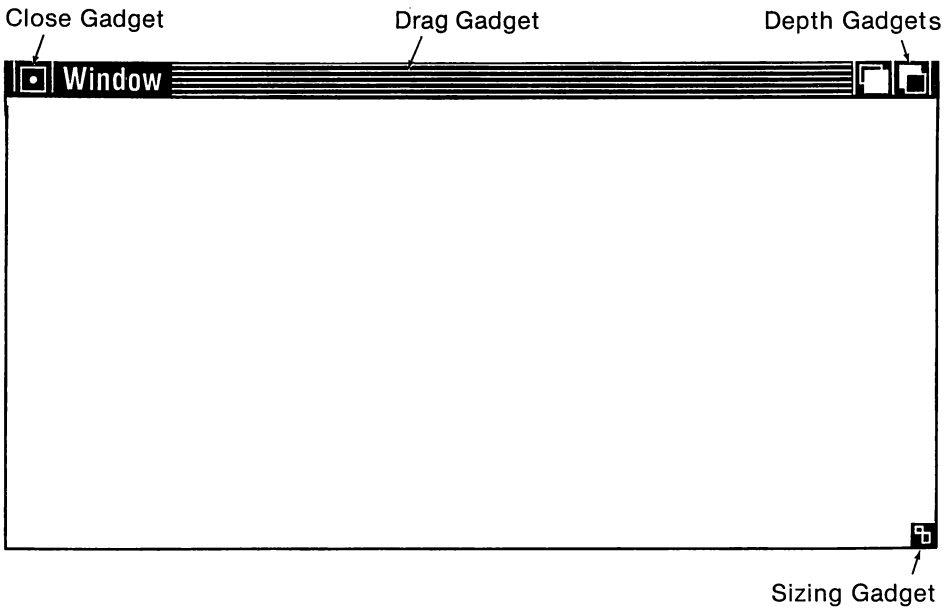
The Sizing and Depth Gadgets can be used for screens as well as windows. In fact, when a screen is opened, these two gadgets are automatically attached. System gadgets must be specifically assigned to a window, however, either at the time of window creation or through the *AddGadget()* function. Figure 3-6 illustrates these gadgets.

System gadgets always appear in the same place in the borders of a window or screen. Because of this, they represent a consistent interface to the user. No matter what application is being run:

- The Sizing Gadget is always in the lower right-hand corner of the display.
- The Depth Gadget is in the upper right-hand corner.
- The Drag Gadget is found in the title bar.
- The Close Gadget resides in the upper left-hand corner of the window or screen.

These locations are within the borders of the window or screens. These borders are adjusted to a greater width necessary for displaying them.

Figure 3-6. Illustrating the system gadgets



It is easy to add the system gadgets to a window at the time of its creation. This is done through the *Flags* field of the NewWindow structure. Each gadget has its own flag:

- WINDOWSIZING indicates a gadget that will allow the user to change the size of an open window.
- WINDOWDEPTH installs a gadget that will allow the user to move one window in front of another.
- WINDOWDRAG creates a gadget that will allow the window to be moved by the mouse.
- WINDOWCLOSE indicates that the user wishes to shut down a window.

By specifying one or more of these flags, the corresponding gadget will be automatically placed in the window when it is displayed.

Listing 3-13 illustrates a program that creates a window containing these system gadgets. In fact, the program opens two windows in a high-resolution custom screen; each has the full range of system gadgets. To specify these gadgets, add their appropriate flags to the *Flags* member of the NewWindow structure.

Listing 3-13. Endowment of two windows with the standard gadgets.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Screen *Scrn;
struct Window *wind0,*wind1;

main()
{
 ULONG flags;
 SHORT x,y,w,h,d;
 USHORT mode;
 UBYTE *name,c0,c1;
 VOID delay_func();

OpenAll();

 /*  ======Open a hi-res custom screen==== */

  name="The Gadget Screen";
  y=0;
  w=640;
  h=200;
  d=3;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,name); /* Add error checking */

 /*  =======Open a window==============*/

  name="Window 1";
  x=20;
  y=20;
  w=300;
  h=100;
  flags=ACTIVATE|WINDOWSIZING|WINDOWDEPTH|WINDOWDRAG|
                              WINDOWCLOSE|SMART_REFRESH;
  c0=-0x01;
  c1=-0x01;

  wind0=(struct Window *)
           make_window(x,y,w,h,name,flags,c0,c1,Scrn); /* Add error
                       checking */

 /*  =======Open another  window==============*/

  name="Window 2";
  x=330;
  y=50;
  w=300;
  h=100;
```

Listing 3-13. (cont.)

```
  flags=ACTIVATE|WINDOWSIZING|WINDOWDEPTH|WINDOWDRAG|
                              WINDOWCLOSE|SMART_REFRESH;
  c0=-0x01;
  c1=-0x01;

  wind1=(struct Window *)
          make_window(x,y,w,h,name,flags,c0,c1,Scrn);

 /*   ======Delay for a bit to show off the window====== */

  delay_func(100);

 /* =========Close down the window then the screen========*/

  CloseWindow(wind0);

  CloseWindow(wind1);

  CloseScreen(Scrn);

}
```

Once you create a window and specify which of the system gadgets you desire, they are—with the exception of the Close Gadget—immediately available. If you position the mouse cursor at the Sizing Gadget, select it, and move the cursor inward, the window gets smaller. An outward movement reverses the process; it gets larger. By using the Drag Gadget, you can move the window vertically and horizontally around the screen. The Depth Gadget allows you to rearrange overlapping windows. All of these functions are performed by Intuition. The commands represented by these gadgets are, in fact, trapped and never even reach the application controlling the window. There are two exceptions: the Close Gadget and the *size verify* function. Both of these must be handled explicitly by the program that controls the window. They are not handled automatically.

The Close Gadget does not affect the display of its window. If you indicate through it that the window is to be shut down, Intuition sends a message to the controlling application that this particular gadget was selected. It never takes it upon itself to close down a window. It is always necessary—except perhaps in the case of small demonstration programs—to perform clean-up and bookkeeping operations on an application, before it can leave the screen. In any case, Intuition leaves it up to the application whether or not to actually close the window. Similarly, you can set a flag in the NewWindow structure that will perform the same kind of hold on the Sizing Gadget. This is the SIZEVERIFY flag; it goes in the *IDCMPFlags* field of the NewWindow structure. We will return to this later when we discuss the IDCMP input/output system.

Our example also shows a new parameter, which must be set to support

the Sizing Gadget. You must specify both the minimum and the maximum size that a window can change. This is accomplished by setting *MinWidth*, *MinHeight*, *MaxWidth*, and *MaxHeight* in the NewWindow structure. Note that a window does not have to initially appear at its minimum size, but if you initialize the *MinWidth* or *MinHeight* fields to 0, these will be automatically set to these initial values. In the example, we have set the minimum values to 1. This will not allow the window to disappear from the screen, but it does allow the user to shrink it so that it nearly disappears.

Application-Specific Gadgets

Intuition also gives you the option of creating a customized gadget to meet a special-purpose input situation. These special-purpose gadgets can take on many shapes and formats, and are frequently displayed as striking graphic images. Their form is limited only by the imagination of the programmer. In this chapter we can only scratch the surface and talk about the technical requirements.

Custom gadgets are defined through a structure data type. This one takes the form:

```
struct Gadget {
     struct Gadget *NextGadget;
     SHORT LeftEdge,TopEdge,
           Width,Height;
     USHORT Flags,
           Activation,
           GadgetType;
     APTR  GadgetRender,
           SelectRender,
     struct IntuiText *GadgetText;
     LONG  MutualExclude;
     APTR  SpecialInfo;
     USHORT GadgetID;
     APTR  UserData;
}
```

Only a few of these fields concern you now. More will be of interest to you later, when we turn our attention to drawing gadgets instead of merely writing out text.

LeftEdge and *TopEdge* are concerned with positioning the gadget in the window. System gadgets are always found in the borders of windows or screens, but customized gadgets can appear anywhere. This is a manifestation of their flexibility. *Width* and *Height* must be set in concert with the two coordinate fields to get a reasonable display.

The *Flags* member controls several display characteristics of the gadget, most importantly, how it is to be highlighted when it is chosen. There are several possibilities:

- GADGHCOMP produces highlighting by turning the color of a chosen gadget to a complementary value.

- GADGHBOX draws a box around the selected item.
- GADGHIMAGE displays an alternate picture, supplied by the application, to indicate selection.
- GADGHNONE is set when no highlighting is desired.

This field controls several other characteristics. Following is a complete description of all values for the gadget *flags* field.

GADGHCOMP.	Highlighting is indicated by setting the select box to complement.
GADGHBOX.	Highlighting is indicated by a box around the select box.
GADGHIMAGE.	Highlighting is indicated by an alternate image or border.
GADGHNONE.	This specifies no highlighting.
GADGIMAGE.	This flag indicates that an image has been supplied for the gadget.
GRELBOTTOM.	This indicates that TopEdge is an offset from the bottom of the containing element.
GRELRIGHT.	This indicates that LeftEdge is be calculated from the right edge of the containing element.
GRELWIDTH.	This is set to interpret Width as an increment to the width of the containing element.
GRELHEIGHT.	This causes Height to be interpreted as an increment to the containing element's height.
SELECTED.	This indicates that the initial state of the gadget is "selected".
GADGDISABLED.	This disables the gadget.

The *Activation* field sets a similar set of characteristics for the gadget itself. TOGGLESELECT, for example, produces a gadget whose state is changed back and forth by the same select field. Each time it is selected by the user, it changes from its current state to its other state. This works much like a pushbutton switch on a lamp.

The *Gadget Type* member indicates one of three possible types:

- BOOLGADGET indicates a boolean or yes-no gadget.
- STRGADGET specifies one looking for character string input.
- PROPGADGET specifies a gadget that will accept and specify a proportional numeric value.

There is one additional type, the *integer*, which is a variant form of the string type.

The *MutualExclude* member allows you to control the interaction of individual gadgets. Specifically, this field indicates which of the other gadgets defined for the window must be de-selected when the gadget in question

becomes the current one. Any gadgets that appear on this list will immediately be de-selected, when this gadget is selected.

Listing 3-14 shows the definition of a string gadget in a window. One additional step was necessary to bring this object to the display: the initialization of a *StringInfo* structure. This is one of two special purpose data types used to initialize the *SpecialInfo* field of the gadget structure. It has the general form:

```
struct StringInfo {
     UBYTE *Buffer,
           *UndoBuffer;
     SHORT BufferPos,
           MaxChars,
           DispPos,
           UndoPos,
           NumChars,
           DispCount,
           CLeft,CTop;
     struct Layer *LayerPtr;
     LONG  LongInt;
     struct KeyMap *AltKeyMap;
};
```

where

Buffer points to a buffer.

UndoBuffer points to a backup buffer.

MaxChars contains the number of characters in the buffer. This includes the '*\0*' character.

BufferPos indicates the initial position of the cursor.

DispPos is the position of the first displayed character.

UndoPos indicates the cursor position in the undo buffer.

NumChars is the current number of characters in the buffer.

DispCount indicates the number of characters visible.

CLeft, CTop is the offset of the containing box.

LayerPtr points to the Layers structure.

LongInt contains the value if this is an integer gadget.

AltKeyMap points to an alternate key map.

Only a few fields need to be set to implement this object.

Buffer points to an area in the memory that is set to receive the characters that will come in from the gadget. It may be preset with a value; this preset value can be replaced by the user. If no value is entered, the preset value becomes default value. The *DispPos* field indicates which characters in this default string will be displayed. In our example, we show the entire string, so this value is 0. It is also necessary to indicate to Intuition the size of the string expected; this is done through the *MaxChar* field. *BufferPos*

indicates the initial position of the cursor in this buffer. Our example puts this, too, at the beginning.

Listing 3-14. Endowment of a window with a string gadget.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Screen *Scrn;
struct Window *wind0,*wind1;
struct Gadget gadget;
struct StringInfo info;

main()
{
 ULONG flags;
 SHORT x,y,w,h,d;
 USHORT mode;
 UBYTE *name,c0,c1;
 VOID delay_func(),OpenALL();
 char dobuffer[80],undobuffer[80];

  OpenALL(); /* Add error checking */

 /*  ======First create a gadget========= */

  strcpy(dobuffer,"Enter New Text Here");

  info.Buffer=dobuffer;
  info.UndoBuffer=undobuffer;
  info.MaxChars=80;
  info.BufferPos=0;
  info.DispPos=0;

  gadget.NextGadget=NULL;
  gadget.LeftEdge=40;
  gadget.TopEdge=40;
  gadget.Width=200;
  gadget.Height=75;
  gadget.Flags=GADGHCOMP;
  gadget.Activation=TOGGLESELECT;
  gadget.GadgetType=STRGADGET;
  gadget.GadgetRender=NULL;
  gadget.SelectRender=NULL;
  gadget.GadgetText=NULL;
  gadget.MutualExclude=NULL;
  gadget.SpecialInfo=(APTR)&info;
  gadget.GadgetID=NULL;
  gadget.UserData=NULL;

 /*  ======Open a hi-res custom screen==== */

  name="The Gadget Screen";
  y=0;
  w=640;
```

Listing 3-14. (cont.)

```
    h=200;
    d=3;
    c0=0x00;
    c1=0x01;
    mode=HIRES;

    Scrn=(struct Screen *)
            make_screen(y,w,h,d,c0,c1,mode,name); /* Add error checking */

  /*  =======Open a window==============*/

    name="Window 1";
    x=20;
    y=20;
    w=400;
    h=150;
    flags=ACTIVATE|WINDOWSIZING|WINDOWDEPTH|WINDOWDRAG|
                                  WINDOWCLOSE|SMART_REFRESH;
    c0=-0x01;
    c1=-0x01;

    wind0=(struct Window *)
             make_window(x,y,w,h,name,flags,c0,c1,Scrn,&gadget);

  /*   ======Delay for a bit to show off the window====== */

    delay_func(100);

  /* =========Close down the window then the screen========*/

    CloseWindow(wind0);

    CloseScreen(Scrn);

}
```

The *UndoBuffer* is an optional field. If specified with something other than NULL, it is used to save the initial string value. This initiates the built-in *undo* editing function: the sequence "Right Amiga Key—Q" will clear the current buffer value and return the original string of characters. The *UndoBuffer* may be shared among all the gadgets in a window, but it must be large enough to hold the largest string. We have implemented the *UndoBuffer* in our example.

Once a gadget has been defined, it is implemented by assigning it to the *FirstGadget* field in the NewWindow structure. It is then added to the window when the window is opened. The *AddGadget()* function allows us to put new gadgets onto the list of an open window. *RemoveGadget()* performs the complementary task. The *RefreshGadget()* function will cause it to appear.

Listing 3-15 shows an example of an integer gadget. This is a string

gadget whose values are restricted to strings of digits. It is set up in just the same way as our earlier example. It, too, uses a StringInfo structure. The difference is the setting of the LONGINT flag in the *Activation* field of the gadget structure.

Listing 3-15. Endowment of a window with an integer gadget.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Screen *Scrn;
struct Window *wind0,*wind1;
struct Gadget gadget;
struct StringInfo info;

main()
{
 ULONG flags;
 SHORT x,y,w,h,d;
 USHORT mode;
 UBYTE *name,c0,c1;
 VOID delay_func(),OpenALL();
 char dobuffer[80],undobuffer[80];

  OpenALL();

 /*  ======First create a gadget========= */

  strcpy(dobuffer,"0");

  info.Buffer=dobuffer;
  info.UndoBuffer=undobuffer;
  info.MaxChars=80;
  info.BufferPos=0;
  info.DispPos=0;

  gadget.NextGadget=NULL;
  gadget.LeftEdge=40;
  gadget.TopEdge=40;
  gadget.Width=200;
  gadget.Height=75;
  gadget.Flags=GADGHCOMP;
  gadget.Activation=TOGGLESELECT|LONGINT;
  gadget.GadgetType=STRGADGET;
  gadget.GadgetRender=NULL;
  gadget.SelectRender=NULL;
  gadget.GadgetText=NULL;
  gadget.MutualExclude=NULL;
  gadget.SpecialInfo=(APTR)&info;
  gadget.GadgetID=NULL;
  gadget.UserData=NULL;

 /*  ======Open a hi-res custom screen==== */

  name="The Gadget Screen";
```

Listing 3-15. (cont.)

```
    y=0;
    w=640;
    h=200;
    d=3;
    c0=0x00;
    c1=0x01;
    mode=HIRES;

    Scrn=(struct Screen *)
            make_screen(y,w,h,d,c0,c1,mode,name);

  /*  =======Open a window==============*/

    name="Window 1";
    x=20;
    y=20;
    w=400;
    h=150;
    flags=ACTIVATE|WINDOWSIZING|WINDOWDEPTH|WINDOWDRAG|
                                WINDOWCLOSE|SMART_REFRESH;
    c0=-0x01;
    c1=-0x01;

    wind0=(struct Window *)
             make_window(x,y,w,h,name,flags,c0,c1,Scrn,&gadget);

  /*   ======Delay for a bit to show off the window====== */

    delay_func(100);

  /* =========Close down the window then the screen========*/

    CloseWindow(wind0);

    CloseScreen(Scrn);

}
```

Menus

Everyone who programs is familiar with the notion of a *menu*: a list of choices that affect the flow of a program by offering the user a selection of options for program control.

The menu is one of Intuition's most basic data objects. As such it is easy to define and easy to set up for dramatic display. Unlike gadgets, which can be in a window or in a screen, the menu is solely a creature of windows. Each window may contain a linked list of such menus—the menu strip. The menu always appears in the title bar of the enclosing screen. When chosen by the right mouse button, the menu rolls down from the top.

Each menu consists of a table of choices. The user must indicate which item or items listed in this table are desired. There are several methods of choice, dependent both upon the design and the nature of the items in question. The primary methods are:

1. Toggles that stay on until explicitly turned off
2. Choices that remain as long as the mouse button is depressed

It is also possible to set up a menu so that several items can be selected by touching each in turn with the mouse cursor.

Toggled items share an important characteristic: they can be set to be mutually exclusive. Choosing one item precludes the choice of others in the prescribed list. Moreover, the choice of a mutually exclusive alternative to an item that is presently toggled *on* causes that item to be de-selected.

Although menus depend heavily on the Intuition interface of windows and screens and the convenience of pointing with the mouse, it is possible to set up a keyboard alternative for all or a selected set of menu items. These alternatives use the special Amiga keys on the keyboard to define an escape sequence of characters, which will automatically choose the menu item in question without resort to the menu. When a keyboard alternative is set up, a special mark is displayed in the visual menu to indicate that this is a possibility.

Defining Menus and Menu Items

A menu is defined by a properly initialized menu structure. Unlike the window, screen, or even the gadget structure, this is a relatively simple data object.

```
struct Menu {
     struct Menu   *NextMenu;
     SHORT  LeftEdge,TopEdge,
            Width,Height;
     USHORT Flags;
     BYTE   *MenuName;
     struct MenuItem *FirstItem;
};
```

The first field, *NextMenu*, is the link to the next menu in the chain for this window. There is only a single string of menus in each window. Remember to set this field either to the address of the next menu or to NULL, if this is the last one.

LeftEdge sets the position of the menu header in the screen title bar; it indicates how far from the left-hand side of the display the header will appear. The *Width* field indicates the horizontal size of the menu header and its corresponding select box. In the current implementation of Intuition, both *TopEdge* and *Height* are not used. All menu headers appear at the top of the screen title bar.

The *Flags* field allows the application to communicate with Intuition. Currently two flag values are defined and set by Intuition:

- MIDRAWN indicates the current display state of the Menu—whether or not the menu is being shown to the user.
- MENUENABLED indicates whether or not a particular menu will be available to the user.

If the MENUENABLED flag is not set, then the menu is disabled. If the flag is set, however, the menu can be controlled by the functions *OnMenu()* and *OffMenu*. The former enables, the latter disables the menu. The format for these functions is as follows:

```
OnMenu(w_ptr,m_num)
```

where

w_ptr points to a window.

m_num is a menu number.

This function activates menu, menu item, or sub-item according to the m_num identifier.

```
OffMenu(w_ptr,m_num)
```

where

w_ptr is a pointer to a window.

m_num is a menu number.

This function de-activates the corresponding object.

It is important to note that even if the menu is to be initially disabled, this flag must be set and the menu disabled through the function. Failure to do this will result in a permanently disabled function.

MenuName is a pointer to a character string that contains the text that is to appear in the menu header. It is the title of the menu. As a matter of style, it is important that this string fit nicely into the specified width of this header. The menu structure serves to set out the header and the title, and specifies the position and width of the object. In order to create a complete menu, we must also have some choices for the user to make. These choices are added through the initialization of a *MenuItem* structure. Each item in the menu is represented by one of these structures, connected together in a linked list. The *FirstItem* field in the menu structure points to the head of this list.

The MenuItem structure consists of eleven fields:

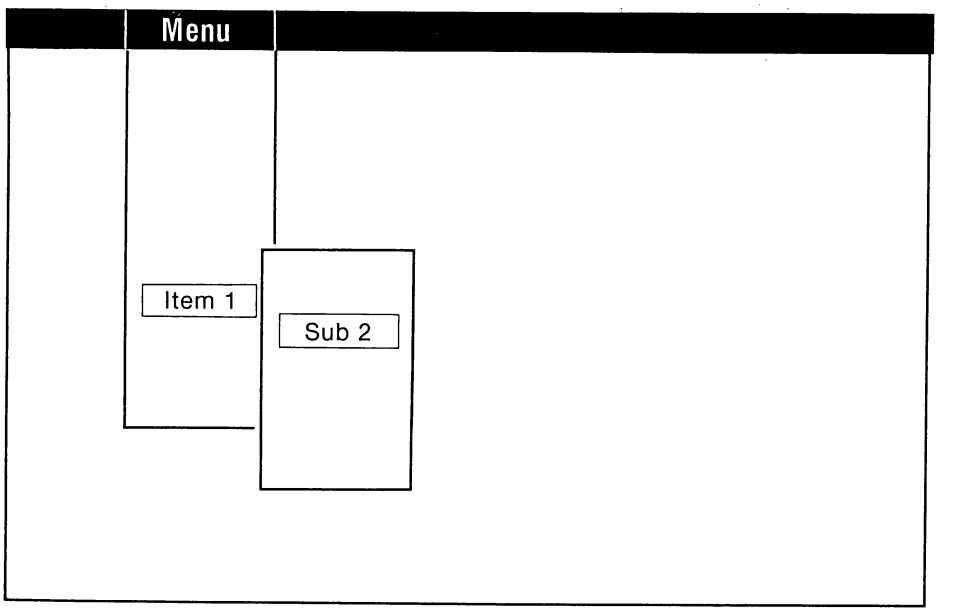
```
struct MenuItem {
     struct MenuItem  *NextItem;
     SHORT LeftEdge,TopEdge,Width,Height;
     USHORT Flags;
     LONG MutualExclude;
     APTR ItemFill;
     BYTE Command;
     struct MenuItem *SubItem;
     USHORT NextSelect;
};
```

This structure is the real workhorse of the menu subsystem. It is more complex than the menu structure itself, although many of its fields are optional. There are two pointer members in this structure.

- *NextItem* points to the next structure in the chain of items that define the menu. The last structure in this chain must set this field to NULL.
- *SubItem* defines another linked list attached to the item; these are also defined using the *Item* structure. The *SubItem* field can support its own dependent linked list.

Figure 3-7 details the relationship of items and sub-items.

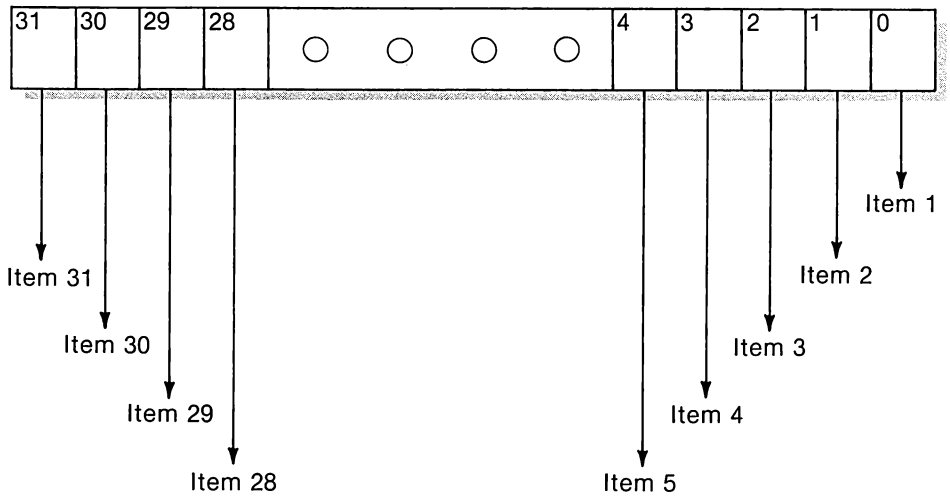
Figure 3-7. The relationship of item and sub-item



Each item in the menu is displayed in its own select box. This is the area that the mouse cursor must access in order to choose the item. *LeftEdge* and *TopEdge* position the select box. As with all Intuition structures, the point whose coordinate is represented by these two fields is relative to the left-hand corner of the enclosing structure, the menu box. The *Width* and *Height* fields round out the item select box definition. It should be noted that the select box need not have the same dimensions as the menu header.

The *MutualExclude* flag is used to specify which items in this menu are incompatible with the item being defined. Any items indicated here will be automatically de-selected whenever the user chooses this item. The field itself is a bit map defined on a long word. This puts a limit of thirty-two on the number of items that can be mutually excluded. Each bit position is assigned to a particular item number. A 1 bit in the position indicates a chosen item. Figure 3-8 illustrates this member of the structure; it is only valid for toggled items.

Figure 3-8. Setting the MutualExclude flag for a menu



Itemfill contains a pointer to one of two structures:

1. If the item is to be rendered by text, it points to an *IntuiText* structure.
2. If the item is to be a graphic one, then the field must contain the address of a user-defined *BitMap*. This latter is an area of memory formatted and managed to store an image of the display.

The *SelectFill* field also points to one or the other of these structures, to specify the highlighting of a chosen item. The *Command* field allows us to specify an alternate keyboard sequence to choose the item. This is an escape sequence defined, first of all, by one of the special Amiga keys on either side of the space bar. This escape sequence allows the user to directly choose a menu and item without recourse to the screen or window display. Once this command sequence is trapped, it is treated no differently than if the menu had been accessed in the orthodox way.

As in other structures, the *Flags* field is used to communicate with Intuition on behalf of the particular item being defined. For menu items, this set of flags is correspondingly complex, since they control so many of the display parameters.

The CHECKIT flag is used to specify the kind of item being defined. If this flag is set, you are specifying a toggle item—one that is turned on and off by subsequent selections. If the flag is unset, the item is only selected momentarily while the mouse cursor is positioned over it and the button pressed. If CHECKED is also set, a check mark is displayed by the item when it is

shown. It should be noted here that extra space must be left for this checkmark when declaring the dimensions of the select box for this item.

The ITEMTEXT flag is set if the item is a text-only one. This is complementary to the *ItemFill* field and indicates which structure this pointer indicates. COMMSEQ indicates that an alternative command sequence has been defined.

ITEMENABLED functions in the same way as the MENUENABLE flag. If this is not set, the item is not enabled and its status cannot be changed. The display is "ghosted" to indicate this to the user. If this flag is set, then the status of the item can be manipulated by *OnMenu()* or *OffMenu()*. These perform the same function on individual items as they do on whole menus.

When a menu item is selected, its display is highlighted. The *Flags* field contains a specification which sets the form of this highlighting.

- HIGHCOMP changes the entire select box to its binary complement.
- HIGHBOX encloses the select box with an outer rectangle.
- HIGHIMAGE replaces the original display with the alternative specified in the *SelectFill* field.
- HIGHNONE turns off any highlighting of the display.

There is no default. One of these alternatives must be explicitly specified.

Intuition sets the ISDRAWN and HIGHTEM flags. The former indicates that an item's sub-items are being displayed. It is cleared when this is no longer the case. The latter flag is set to show highlighting of an item.

Creating a Menu

Once you have defined each item in the menu, combined these items into a list, and attached it to a menu definition, you still have to associate it with a particular window. This association is controlled by *SetMenuStrip()* and *ClearMenuStrip()*. These two functions allow you to dynamically create and change the menus within your applications. Two additional functions *OnMenu()* and *OffMenu()* afford even greater control by allowing you to turn specific menus or menu items on and off, without removing them from their respective lists. Finally, Intuition offers a function, *ItemAddress()*, to capture the address of a particular MenuItem structure.

SetMenuStrip() takes a pointer to a window and a pointer to a menu structure as arguments. Intuition automatically attaches the menu strip defined by this pointer to the window in question.

There may be many menus in a window—even unrelated ones— but they must all be connected together in this menu strip. Each window has only one such strip. In recognition of this fact, the *ClearMenuStrip()* function requires only a window pointer, to remove all menus. Any application that is to change a menu or item must first clear the menu strip and then make another call to

SetMenuStrip(). This process can occur any number of times. The format of these two functions is as follows:

```
SetMenuStrip(w_ptr,m_ptr)
```

where

w_ptr points to a window.

m_ptr points to the first menu in the menu strip.

This function will install the menu strip in the window.

```
ClearMenuStrip(w_ptr)
```

where

w_ptr points to a window.

This function will remove the current menu strip from the window.

The complementary functions *OnMenu()* and *OffMenu()* control the menu and items once they are established in the window. Each function takes a window pointer and a *MenuNumber* as an argument, and performs its task on the object so identified. The *MenuNumber* is an Intuition variable that identifies the menu-related object currently picked; this quantity allows you to specify either an entire menu, an item, or a sub-item. An object that is disabled appears to the user with a light pattern of white dots across it (ghosting) to indicate its status. The format for these functions is:

```
OnMenu(w_ptr,m_number)
```

where

w_ptr points to a window.

m_number is a menu item number.

This function enables the specified menu or menu item.

```
OffMenu(w_ptr,m_number)
```

where

w_ptr points to a window.

m_number is a menu item number.

This function disables the specified menu or menu item.

The *menu number* is an important parameter for all menu-related functions. You can use it to do selective enabling or disabling of particular menu objects; but it is also important for communicating choices to the controlling application. This number is sent through Intuition's IDCMP facility, a specialized communication method peculiar to Intuition. We will discuss the medium and technique for this facility in a later section. Once you have this value, it is still necessary to decode it into its exact reference.

The menu number is a composite value, giving the user's choice as:

- A particular menu
- A particular item in that menu
- A sub-item attached to the item

These values are combined into a single LONG word value. Each menu is assigned an ordinal value in the menu strip, which is the menu number. Each item is similarly numbered within its menu, and the same is true of each sub-item. Intuition supplies several macros to perform the necessary decoding.

MENUNUM( ) returns the menu number.

ITEMNUM( ) finds the item number.

SUBNUM( ) gives us the sub-item number.

You need all three of these numbers to define a reference since a sub-item is relative to an item, which in turn is relative to a menu.

The absence of a menu selection is signaled by the value MENUNULL. In addition, there are three flags which you can use to indicate a null condition to Intuition: NOMENU, NOITEM, and NOSUB. Although the reference objects of these latter flags are obvious, how they are used may not be. One important use for these constant values is in the *OnMenu( )/OffMenu( )* functions:

- *Setting the item field to NOITEM causes the function to operate on the* entire menu.
- *Setting the sub-item field to NOSUB affects only the item.*
- Setting none of the fields in a menu number causes the function to work only on the indicated sub-item.

Finally, the function *ItemAddress( )* takes a pointer to a *MenuStrip* and a *MenuNumber* and returns a pointer to the object thus specified. These menu-related functions are summarized as follows:

```
address=ItemAddress(m_strip,m_number)
```

where

address is an address value.

m_strip points to the first menu in the menu strip.

m_number is the number of the menu or menu item.

This function will find the address of a menu item.

Now that we've talked so much about all the details involved in creating a menu, Listing 3-16 shows the definition of a single menu in a window—the most basic situation. In this example nothing can be done with the menu except display it. Even merely noting selection must wait until we cover basic window-related input/output. The function *CreateMes( )* uses the IntuiText structure to create the text for each menu item. The process of the examples that follow is simple and straightforward:

- First, we defined a list of three MenuItem structures.

- We connected these structures through the *NextItem* field of each structure, taking care to set the last NextItem structure to NULL.
- We attached this linked list to our menu structure using its *FirstItem* field.

A call to *SetMenuStrip()* completed the menu processing. Note that we called *ClearMenuStrip* just before we closed the window and exited the program.

Listing 3-16. Creation of a menu in a window. This shows only the creation and display; nothing is done with the menu items.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Window *Wind,*NoBorder;

main()
{
 ULONG flags;
 SHORT x,y,w,h;
 UBYTE name[60];
 VOID delay_func(),OpenALL(),CreateMes();
 struct Menu Menu1;
 struct MenuItem m0,m1,m2;
 struct IntuiText t0,t1,t2;

  OpenALL(); /* Add error checking */

  /*  ===========Set up a menu===========*/

  CreateMes(&t0,CHECKWIDTH+2,0,"Choice 0");

  m0.NextItem=&m1;
  m0.LeftEdge=5;
  m0.TopEdge=0;
  m0.Width=100;
  m0.Height=10;
  m0.Flags=CHECKIT|CHECKED|ITEMTEXT|HIGHCOMP|ITEMENABLED;
  m0.MutualExclude=NULL;
  m0.ItemFill=(APTR)&t0;
  m0.SelectFill=NULL;
  m0.Command=NULL;
  m0.SubItem=NULL;

  CreateMes(&t1,CHECKWIDTH+2,0,"Choice 1");

  m1.NextItem=&m2;
  m1.LeftEdge=5;
  m1.TopEdge=10;
  m1.Width=100;
  m1.Height=10;
  m1.Flags=CHECKIT|ITEMTEXT|HIGHCOMP|ITEMENABLED;
  m1.MutualExclude=NULL;
```

Listing 3-16. (cont.)

```
m1.ItemFill=(APTR)&t1;
m1.SelectFill=NULL;
m1.Command=NULL;
m1.SubItem=NULL;

CreateMes(&t2,CHECKWIDTH+2,0,"Choice 2");

m2.NextItem=NULL;
m2.LeftEdge=5;
m2.TopEdge=20;
m2.Width=100;
m2.Height=20;
m2.Flags=CHECKIT|ITEMTEXT|HIGHCOMP|ITEMENABLED;
m2.MutualExclude=NULL;
m2.ItemFill=(APTR)&t2;
m2.SelectFill=NULL;
m2.Command=NULL;
m2.SubItem=NULL;

Menu1.NextMenu=NULL;
Menu1.LeftEdge=0;
Menu1.TopEdge=0;
Menu1.Width=200;
Menu1.Height=100;
Menu1.Flags=MENUENABLED;
Menu1.MenuName="My First Menu";
Menu1.FirstItem=&m0;


/*  ======Open a borderless window======*/

x=y=0;
w=640;
h=200;
flags=ACTIVATE|BORDERLESS;
NoBorder=(struct Window *)make_window(x,y,w,h,NULL,flags);


/*   ======Open a plain window=====  */

strcpy(name,"Plain Window ");
x=y=20;
w=300;
h=100;
flags=ACTIVATE;
Wind=(struct Window *)make_window(x,y,w,h,name,flags);

/*   ==============Open up the menu====================== */

SetMenuStrip(Wind,&Menu1);

/*   ======Delay for a bit to show off the windows====== */
```

Listing 3-16. (cont.)

```
  delay_func(100);

 /* =========Close down the windows in order========*/

  ClearMenuStrip(Wind);

  CloseWindow(Wind);

  delay_func(10);

  CloseWindow(NoBorder);
}

VOID CreateMes(x,left,top,mesg)
struct IntuiText *x;
SHORT left,top;
UBYTE *mesg;
{
 x->FrontPen=0;
 x->BackPen=1;
 x->DrawMode=JAM1;
 x->LeftEdge=left;
 x->TopEdge=top;
 x->ITextFont=NULL;
 x->IText=mesg;
 x->NextText=NULL;
}
```

Listing 3-17 creates a slightly more complex case; it opens two menus in a window. The important differences between this and the earlier example are:

- We had to define two linked lists of MenuItem structures and attach them to the menu structure.
- We had to create a linked list of menu structures.

Listing 3-17. Creation of two menus in a window. This shows only the creation and display, nothing is done with the menu items.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Window *Wind,*NoBorder;

main()
{
 ULONG flags;
 SHORT x,y,w,h;
 UBYTE name[60];
 VOID delay_func(),OpenALL(),CreateMes(),CreateItem();
```

Listing 3-17. (cont.)

```
struct Menu Menu1,Menu2;
struct MenuItem m0,m1,m2,x0,x1;
struct IntuiText t0,t1,t2,xt0,xt1;

 OpenALL();

 /*  ===========Set up a menu===========*/

 CreateMes(&t0,CHECKWIDTH+2,0,"Choice 0");
 CreateItem(&t0,&m0,&m1,5,0,CHECKED);

 CreateMes(&t1,CHECKWIDTH+2,0,"Choice 1");
 CreateItem(&t1,&m1,&m2,5,10,0);

 CreateMes(&t2,CHECKWIDTH+2,0,"Choice 2");
 CreateItem(&t2,&m2,NULL,5,20,0);

 Menu1.NextMenu=&Menu2;
 Menu1.LeftEdge=0;
 Menu1.TopEdge=0;
 Menu1.Width=200;
 Menu1.Height=100;
 Menu1.Flags=MENUENABLED;
 Menu1.MenuName="My First Menu";
 Menu1.FirstItem=&m0;

 /* =======Set up a second menu==========*/


 CreateMes(&xt0,CHECKWIDTH+2,0,"Choice 1");
 CreateItem(&xt0,&x0,&x1,5,10,0);

 CreateMes(&xt1,CHECKWIDTH+2,0,"Choice 2");
 CreateItem(&xt1,&x1,NULL,5,20,0);

 Menu2.NextMenu=NULL;
 Menu2.LeftEdge=220;
 Menu2.TopEdge=0;
 Menu2.Width=200;
 Menu2.Height=100;
 Menu2.Flags=MENUENABLED;
 Menu2.MenuName="My Second Menu";
 Menu2.FirstItem=&x0;



 /*  ======Open a borderless window======*/

 x=y=0;
 w=640;
 h=200;
 flags=ACTIVATE|BORDERLESS;
 NoBorder=(struct Window *)make_window(x,y,w,h,NULL,flags);
```

Listing 3-17. (cont.)

```
 /*   ======Open a plain window=====  */

  strcpy(name,"Plain Window ");
  x=y=20;
  w=300;
  h=100;
  flags=ACTIVATE;
  Wind=(struct Window *)make_window(x,y,w,h,name,flags);

 /*   ==============Open up the menu====================== */

  SetMenuStrip(Wind,&Menu1);

 /*   ======Delay for a bit to show off the windows====== */

  delay_func(100);

 /* =========Close down the windows in order========*/

  ClearMenuStrip(Wind);

  CloseWindow(Wind);

  delay_func(10);

  CloseWindow(NoBorder);
}

VOID CreateMes(x,left,top,mesg)
struct IntuiText *x;
SHORT left,top;
 UBYTE *mesg;
{
 x->FrontPen=0;
 x->BackPen=1;
 x->DrawMode=JAM1;
 x->LeftEdge=left;
 x->TopEdge=top;
 x->ITextFont=NULL;
 x->IText=mesg;
 x->NextText=NULL;
}

VOID CreateItem(name,item,next,left,top,flags)
UBYTE *name;
USHORT left,top;
ULONG flags;
struct MenuItem *item,*next;

/* This function will set up a simple MenuItem structure */
{
  item->NextItem=next;
  item->LeftEdge=left;
```

Listing 3-17. (cont.)

```
    item->TopEdge=top;
    item->Width=100;
    item->Height=10;
    item->Flags=CHECKIT|ITEMTEXT|HIGHCOMP|ITEMENABLED|flags;
    item->MutualExclude=NULL;
    item->ItemFill=(APTR)name;
    item->SelectFill=NULL;
    item->Command=NULL;
    item->SubItem=NULL;
}
```

Listing 3-18 puts menus in two windows. This requires that we create two disparate linked lists of menus and make two calls to *SetMenuStrip()*, as well as two to *ClearMenuStrip*.

Listing 3-18. Creation of menus in two windows. This shows only the creation and display, nothing is done with the menu items.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Window *Wind,*NoBorder;

main()
{
 ULONG flags;
 SHORT x,y,w,h;
 UBYTE *name;
 VOID delay_func(),OpenALL(),CreateMes(),CreateItem();
 struct Menu Menu1,Menu2,Menu3;
 struct MenuItem m0,m1,m2,x0,x1,p0,p1;
 struct IntuiText t0,t1,t2,xt0,xt1,pt0,pt1;

  OpenALL();

  /*  ===========Set up a menu===========*/

  CreateMes(&t0,CHECKWIDTH+2,0,"Choice 0");
  CreateItem(&t0,&m0,&m1,5,0,CHECKED);

  CreateMes(&t1,CHECKWIDTH+2,0,"Choice 1");
  CreateItem(&t1,&m1,&m2,5,10,0);

  CreateMes(&t2,CHECKWIDTH+2,0,"Choice 2");
  CreateItem(&t2,&m2,NULL,5,20,0);

  Menu1.NextMenu=&Menu2;
  Menu1.LeftEdge=0;
  Menu1.TopEdge=0;
  Menu1.Width=200;
```

Listing 3-18. (cont.)

```
Menu1.Height=100;
Menu1.Flags=MENUENABLED;
Menu1.MenuName="My First Menu";
Menu1.FirstItem=&m0;

/* =======Set up a second menu==========*/


CreateMes(&xt0,CHECKWIDTH+2,0,"Choice 1");
CreateItem(&xt0,&x0,&x1,5,10,CHECKED);

CreateMes(&xt1,CHECKWIDTH+2,0,"Choice 2");
CreateItem(&xt1,&x1,NULL,5,20,0);

Menu2.NextMenu=NULL;
Menu2.LeftEdge=220;
Menu2.TopEdge=0;
Menu2.Width=200;
Menu2.Height=100;
Menu2.Flags=MENUENABLED;
Menu2.MenuName="My Second Menu";
Menu2.FirstItem=&x0;


/* =======And a third==========*/


CreateMes(&pt0,CHECKWIDTH+2,0,"Choice 1");
CreateItem(&pt0,&p0,&p1,5,10,0);

CreateMes(&pt1,CHECKWIDTH+2,0,"Choice 2");
CreateItem(&pt1,&p1,NULL,5,20,0);

Menu3.NextMenu=NULL;
Menu3.LeftEdge=0;
Menu3.TopEdge=0;
Menu3.Width=200;
Menu3.Height=100;
Menu3.Flags=MENUENABLED;
Menu3.MenuName="Second Window Menu";
Menu3.FirstItem=&p0;



/*  ======Open a borderless window======*/
name="A Window without Borders";
x=y=0;
w=640;
h=200;
flags=ACTIVATE|BORDERLESS;
NoBorder=(struct Window *)make_window(x,y,w,h,name,flags);


/*   ======Open a plain window=====  */
```

Listing 3-18. (cont.)

```
   name="Window: 2 Cents Plain";
   x=y=20;
   w=300;
   h=100;
   flags=ACTIVATE;
   Wind=(struct Window *)make_window(x,y,w,h,name,flags);

  /*   ==============Open up the menu====================== */

   SetMenuStrip(NoBorder,&Menu3);

   SetMenuStrip(Wind,&Menu1);

  /*   ======Delay for a bit to show off the windows====== */

   delay_func(100);

  /* =========Close down the windows in order========*/

   ClearMenuStrip(Wind);

   ClearMenuStrip(NoBorder);

   CloseWindow(Wind);

   delay_func(10);

   CloseWindow(NoBorder);
}

 IntuitionBase=(struct IntuitionBase *)
            OpenLibrary("intuition.library",INTUITION_REV);

 if(IntuitionBase==NULL)
    exit(FALSE);
}

VOID CreateMes(x,left,top,mesg)
struct IntuiText *x;
SHORT left,top;
 UBYTE *mesg;
{
 x->FrontPen=0;
 x->BackPen=1;
 x->DrawMode=JAM1;
 x->LeftEdge=left;
 x->TopEdge=top;
 x->ITextFont=NULL;
 x->IText=mesg;
 x->NextText=NULL;
}

VOID CreateItem(name,item,next,left,top,flags)
```

Listing 3-18. (cont.)

```
UBYTE *name;
USHORT left,top;
ULONG flags;
struct MenuItem *item,*next;

/* This function will set up a simple MenuItem structure */
{
  item->NextItem=next;
  item->LeftEdge=left;
  item->TopEdge=top;
  item->Width=100;
  item->Height=10;
  item->Flags=CHECKIT|ITEMTEXT|HIGHCOMP|ITEMENABLED|flags;
  item->MutualExclude=NULL;
  item->ItemFill=(APTR)name;
  item->SelectFill=NULL;
  item->Command=NULL;
  item->SubItem=NULL;
}
```

There are still more things that you can do with menus. Some of these are very basic, such as getting input from them. Some are more dramatic—for example, using graphics techniques to create on screen menus.

Requesters

Intuition offers us another menu-like facility for entering values: the *requester*. Whenever a program needs a value from the user, a requester is called for. This object halts the operation of its application and waits for a reply. This is in contrast to the more passive menu, whose calling sequence is completely under the control of the user. The user must explicitly call the menu by moving the mouse cursor to the proper position and pushing the proper buttons. More importantly, a user can leave the menu without entering anything into the program—without making a choice. A requester, in contrast, demands input. Even requesters that can be explicitly controlled by the user must be satisfied once they are called.

Requesters screen locations are more flexible than menus and may be used for some menu activities to greater effect. A menu must be at the top of the screen in the title bar. It is detached from its enclosing window and, in a complicated display containing many windows, could even confuse the user. A requester appears in its associated window and, in fact, can be placed anywhere within this enclosed space. Because of this, a requester can be placed near an object that it directly affects: a request for a color change near a drawing, a frequency input adjacent to the display of its waveform. The effect is more dramatic and more appropriate to the complex displays typical of

large programs—particularly those that take advantage of the Amiga's complex support software.

A requester is defined by its system defined structure.

```
struct Requester {
   struct Requester *OlderRequest;
   SHORT  LeftEdge,TopEdge,Width,Height RelLeft,RelTop;
   struct Gadget   *ReqGadget;
   struct Border   *ReqBorder;
   struct IntuiText *ReqText;
   USHORT Flags;
   UBYTE  BackFill;
   struct ClipRect  ReqCRect;
   struct BitMap   *ImageBMap;
   struct BitMap   ReqBmap;
};
```

As the structure definition shows, much of the power of this object comes from its interaction with the graphics subsystem. The system maintains a linked list of requesters in order of appearance. This supports the nesting of these objects that is a feature of Intuition. *OlderRequest* refers to this activity and is set accordingly by the operating system. *Width* and *Height* define the limits of the box that frames the requester display. This must be big enough to contain all of the text and non-text objects that will be used to create the object. The requester box can be as large as the window—but no larger—or arbitrarily small.

The positioning of the requester box refers to two sets of values. If the requester is to be placed in a fixed position within the window, then the fields *LeftEdge* and *TopEdge* will set this coordinate. However, if you initialize *RelLeft* and *RelTop* instead, the requester box will be positioned near the current position of the cursor. These two fields will set the offset. It is also necessary to set the POINTREL flag in the *Flags* field. It should be noted that *RelLeft* and *RelTop* are advisory; if the offsets specified would place the requester outside the window, the actual values are ignored and it is placed as close to them as is possible. The rest of the fields refer to the requester's interaction with the graphics subsystem.

Before leaving the subject of requesters, there is one useful function that is appropriate to discuss here: *AutoRequest()*. This function automatically creates and installs a boolean requester—one that seeks a yes or no answer. These boolean objects account for a large number of incidents of this data type. The general form of *AutoRequest()* is:

```
AutoRequest(w_ptr,b_text,p_text,n_text,p_flags,n_flags,width,height);
```

where

w_ptr points to a window.

b_text points to a character string that holds the characters to be printed in the body of the requester.

p_text is a pointer to the text associated with the positive response.

n_text is the message associated with the negative response.

p_flags and **n_flags** are IDCMP flags.

width and **height** specify the size of the requester box.

This function will automatically create a requester for an application.

Listing 3-19 shows an example that creates and opens a simple boolean requester using the *AutoRequest()* function. Again, we used the *CreateMes()* function to produce the three IntuiText messages necessary for the requester initialization:

- One to explain what the requester wants
- One to describe the positive choice
- One to describe the negative

Width and *Height* are set at 250 and 100 respectively. We set no special flags in this object. Requester input, like menu input must be through the normal I/O channels.

Listing 3-19. Creation of a very simple requester using the AutoRequest() function.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Screen *Scrn;
struct Window *wind0,*wind1;

main()
{
 ULONG flags;
 SHORT x,y,w,h,d;
 USHORT mode;
 UBYTE *name,c0,c1;
 VOID delay_func(),OpenALL(),CreateMes();
 struct IntuiText prompt,yprompt,nprompt;

 OpenALL();

 /*  ======Open a hi-res custom screen==== */

  name="Requests Now Being Taken";
  y=0;
  w=640;
  h=200;
  d=3;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,name);

 /*  =======Open a window==============*/
```

Listing 3-19. (cont.)

```
  name="Window 1";
  x=20;
  y=20;
  w=400;
  h=150;
  flags=ACTIVATE|WINDOWSIZING|WINDOWDEPTH|WINDOWDRAG|
                              WINDOWCLOSE|SMART_REFRESH;
  c0=-0x01;
  c1=-0x01;

  wind0=(struct Window *)
          make_window(x,y,w,h,name,flags,c0,c1,Scrn,NULL);

 /*   ======Build and display a requester======  */

  CreateMes(&prompt,45,25,"Stop The Music!");
  CreateMes(&yprompt,3,3,"Yes");
  CreateMes(&nprompt,3,3,"No");

  AutoRequest(wind0,&prompt,&yprompt,&nprompt,NULL,NULL,250,100);

  delay_func(100);

 /* =========Close down the window then the screen========*/

  CloseWindow(wind0);
  CloseScreen(Scrn);

}

VOID CreateMes(x,left,top,mesg)
struct IntuiText *x;
SHORT left,top;
UBYTE *mesg;
/* This will prepare a message for display as IntuiText */
{
 x->FrontPen=0;
 x->BackPen=1;
 x->DrawMode=JAM1;
 x->LeftEdge=left;
 x->TopEdge=top;
 x->ITextFont=NULL;
 x->IText=mesg;
 x->NextText=NULL;
}
```

Alerts

Everyone who has programmed on the Amiga has come face to face with one version of the *alert* data object—the "Guru Meditation" box. Alerts are a

kind of requester, but one that is reserved for extreme situations—usually, system or program faults that cannot be reversed. They represent an elegant way for the system to crash, inform the user that it is about to go down, and give whatever information it may possess about the error situation. Although the operating system is the origin of many of the alert messages which a user will receive, it is possible to create application specific ones.

Two kinds of alert objects are recognized by Intuition:

1. Those situations from which it may be possible to back out (RECOVERY_ALERT)
2. Those which will require a reboot of the system (DEADEND_ALERT)

Each of these situations is signaled by the appropriate flag values in a call to the system function, *DisplayAlert()*. For RECOVERY_ALERT, the application will proceed, depending on action by the user. If the left mouse button is pushed, the function returns true; otherwise it is equal to false. In either case, the normal display is returned.

Two additional parameters are necessary to *DisplayAlert()*: a string which comprises the alert message and a height value indicating how many lines it will take up on the screen. Alerts are always displayed from the top of the screen. The format of this function is:

```
DisplayAlert(AlertNumber,Text,Height)
```

where

AlertNumber is either RECOVERY_ALERT or DEADEND_ALERT as appropriate; it is type LONG.

Height indicates how many lines will be necessary for the display.

Text is of the format:
- x coordinate (2 bytes)
- y coordinate (1 byte)
- text to appear in the alert box.
- continuation byte to indicate a possible substring.

Listing 3-20 illustrates a simple alert display. A character string is allocated and initialized with the intended message for the display. Note that the initial three character positions are left blank. These will contain the positioning information (translated into byte format) after the Intuition library is opened.

Listing 3-20. An example of a user defined Alert.

```
#include <exec/types.h>
#include <intuition/intuition.h>

/* set up the Alert's display message taking care to leave the first three
   positions blank */

char mesg[45]="  Help! I'm being held prisoner in RAM!";
```

Listing 3-20. (cont.)

```
main()
{
 OpenAll();

 mesg[0]=0x0000;        /* set up the display parameters for the message */
 mesg[1]=0x64;
 mesg[2]=0x14;

 if(DisplayAlert(RECOVERY_ALERT,mesg,30)) {
   printf("Phew! That was a close one!\n");         /* left mouse button */
   printf("The program will continue\n");
  }
 else {
   printf("Sorry! The program will be stopped\n"); /* right mouse button */
   exit(TRUE);
  }
}
```

The program sets the x and y coordinates in the character string. Note how the 16-bit x coordinate must be assigned in two stages: high order byte and low order byte. Once the proper initialization has occurred, a call to *DisplayAlert()* is made. The value returned by this function—dependent on which mouse button the user pressed—controls a simple if else structure.

Intuition I/O

There is an *input device* that monitors the interface to the outside world. Usually this outside world consists of the keyboard and the mouse. When either or both of these objects produce some value, the input device creates an *input event.* This is a message that reports the value that was produced. Input events can be created by other objects, both internal and external. For example, specialized input devices, a network device, or even internal software can trigger the input device to create one of these special purpose messages.

All input events are merged into an *input stream.* This stream is available to other parts of the Amiga. Individual events can be extracted by different subsystems, while the rest of the stream is ignored. Intuition acts as a filter for the applications that are running under it. Most importantly, it only passes the event stream to the active application.

Intuition provides two ways for an application to receive the input event stream:

1. Intuition can pass it directly through the Direct Communications Message Ports (IDCMP) facility. This provides unprocessed and untranslated input values.
2. Alternately, Intuition can filter this input through the console device.

The console device is a kind of virtual terminal, which will process the input values, doing some translations and reporting out well-behaved values. Values coming out of this device will be ASCII characters or well-behaved control sequences—usually ANSI standard escape sequences.

The IDCMP Facility

The IDCMP facility sends through to the application only raw events. These are completely unprocessed and uninterpreted; the application must make sense of them itself. The first thing that must be done is to choose those events in which the application is interested. Recall that most of the event stream will be passed through by Intuition, although it does trap some events in which it has a proprietary interest. Choice is exercised by setting the IDCMP flags. These flags are found in every object definition in Intuition: windows, screens, gadgets, menus, everything. Furthermore, in order to receive these messages, the application must continuously check the message port that has been provided by Intuition. These events are instances of the *IntuiMessage* object. As with other Intuition objects, this one is defined and manipulated by a specific structure.

Contrast this to the text-only display that comes through the console device. This is in the form of the ASCII character set that is so familiar to computer users. Values that are meant to be interpreted as control messages are translated into escape sequences—strings of characters preceded by the ESC character. All translating performed by the console device is under the control of the application. Translation sequences and key mapping can be altered. It is also possible to open both a console device and an IDCMP port in a single window to get both kinds of input. Similarly, a window can be opened with neither one of these facilities available. Such a window can accept no input.

The IDCMP facility will specifically inform an application about mouse, keyboard, and Intuition-generated events. IDCMP also defines a class of verification functions that allow the application to deal elegantly with asynchronous events, such as menu or requester input. In fact, the only way to access these functions is through the IDCMP.

The IDCMP itself consists of complementary message ports for both the application process and for Intuition. These ports are opened automatically whenever an IDCMP flag is set in the definition of a window. These ports can be manipulated after the window is open by the *ModifyIDCMP()* function.

```
ModifyIDCMP(w_ptr,flags)
```

where

w_ptr points to a window.

flags contains a flag value indicating the desired change.

flags:

NULL indicates whether or not the window is open and closes it.

MOUSEBUTTONS reports the state of the buttons on the mouse.

SELECTDOWN, SELECTUP, MENUDOWN, MENUUP sets Intuition to trap these events.

MOUSEMOVE reports mouse movements in absolute x,y values.

DELTAMOVE reports mouse movements as amounts of change from last position.

GADGETDOWN, GADGETUP indicates these conditions for the gadgets.

CLOSEWINDOWN indicates that this gadget has been picked.

MENUPICK, MENUVERIFY reports these events concerning menu.

REQSET, REQCLEAR indicates the first and the last requestor respectively

REQVERIFY verifies conditions before a requestor is drawn.

NEWSIZE indicates a user has resized the window.

REFRESHWINDOW reports that a window needs refreshing.

SIZEVERIFY causes a drawing to be finished before a resizing.

RAWKEY bypasses the key translator table.

NEWPREFS indicates that preferences have been changed.

DISKINSERTED, DISKREMOVED indicates that these events have occurred.

This function can also be used to modify the IDCMP functions requested for the window. Messages are exchanged via an *IntuiMessage* structure initialized with the desired values.

The form of an IntuiMessage structure is:

```
struct IntuiMessage  {
   struct Message       ExecMessage;
   ULONG                Class;
   USHORT               Code,
                        Qualifier;
   APTR                 IAddress;
   SHORT                MouseX,
                        MouseY;
   ULONG                Seconds,
                        Micros;
   struct Window        *IDCMPWindow;

   struct InutiMessage  *SpecialLink;
};
```

where

ExecMessage is a link to the Exec kernel message system.

Class, Code links this message to Intuition.

Qualifier refers to the input device.

MouseX, MouseY are relative to the upper left corner of the current window.

Seconds, Micros reports the current system clock.

IAddress points to an object associated with the message.

IDCMPWindow points to the window associated with the message.

SpecialLink is used by the system.

The *ExecMessage* and *SpecialLink* fields are used by the operating system to manage and route the message. The other fields contain the information and values necessary to the calling application.

The *Class* field indicates the IDCMP flag value that is being transmitted.

The *Code* field is interpreted in terms of the class of the message. It contains special values such as a menu or MenuItem number. In the case of a RAWKEY event, it contains the generated code value.

The *Qualifier* field is set by the input device and is also useful for RAWKEY situations. It indicates if the value sent has been accompanied by a qualifying event such as a SHIFT or CTRL key value.

MouseX and *MouseY* report the coordinates of the cursor relative to the upper left-hand corner of the window.

The *Seconds* and *Micros* fields contain the current time; this can be evaluated to give the date as well.

Iaddress contains the address of an object significant to the message.

IDCMPWINDOW is the window address for the message.

By interpreting these fields, an application can interpret the IDCMP stream.

The events that generate these IntuiMessages are set by the IDCMP flags. These include:

- MOUSEBUTTONS to report on the status of the buttons on the pointing device. Both up and down events are recognized. The code field of the structure contains either SELECTDOWN, SELECTUP, MENUDOWN, or MENUUP. The latter two are only reported if the RMBTRAP flag is set. Otherwise, Intuition deals directly with these two actions.
- MOUSEMOVE causes a set of x and y values to be reported, indicating the movement of the mouse. This is dependent on either REPORTMOUSE or some gadget's FOLLOWMOUSE flag being set simultaneously. If DELTAMOVE is also set, this report is in the form of a change from last position and not as an absolute coordinate.

Certain flags are associated with a gadget:

- GADGETDOWN is reported under appropriate circumstances if the GADGIMMEDIATE flag has been set. Gadget reports require the setting of the RELVERIFY flag.
- CLOSEWINDOW indicates that this system-defined gadget has been chosen.

There are two menu flags:

- MENUPICK indicates the selection of a menu. The number of the item or sub-item chosen will be in the *Code* field of the IntuiMessage structure.
- MENUVERIFY causes any MENUPICK operation to wait for completion, until the application has responded to the message requesting it. All windows with this flag set must respond before operation can continue. Only the active window can cancel menu operations.

The requester flags are:

- REQSET reports the first requester open in a window.
- REQCLEAR reports the last requester cleared; it is the complement to REQSET.
- REQVERIFY, like its menu counterpart holds a requester pending until a reply from the application is received. Only the first requester is kept waiting.

Window information is also reported.

- NEWSIZE indicates a resizing operation has been performed on the window.
- REFRESHWINDOW sends a message, if a refresh operation is necessary. This is only valid when SIMPLE_REFRESH or SMART_REFRESH have also been set.
- SIZEVERIFY halts a sizing operation until the application signals it to continue.
- ACTIVEWINDOW and INACTIVEWINDOW send a report, indicating that a window has gone into one of these states.

Miscellaneous flags include:

- RAWKEY sends unprocessed keycodes from the keyboard. These values are found in the *Code* field of the structure.
- NEWPREFS sends a report indicating that the system preferences have been altered. A call to *GetPrefs()* will return the new values.
- DISKINSERTED and DISKREMOVED indicate when these disk-oriented events have occurred.

The verification functions operate in a different way from the other IDCMP functions. These send a message and then go to sleep via an Exec *Wait()* function. The activity that they request is halted pending a reply from the receiving task. The function will not proceed until this occurs. Caution is advised with this particular set of functions. There is potential for a system log jam or deadlock here, as tasks are held awaiting permission to complete. One way to ameliorate this problem is to create a monitoring task to manage such potential bottlenecks.

Setting up a monitoring task involves creating and linking two ports: the window port and the monitor task's port. Intuition can open both of these. Alternatively, you can explicitly open a task message port and link it to the window port.

The monitor task will respond to each message and decide what can be done and what must be held. Whatever the decision, the message is replied to immediately, so that the message port can be cleared and a bottleneck avoided. The basic algorithm is

- Read the message.
- Copy the values from the message structure.
- *Reply()* to the message.

The important thing is to keep the message port clear. Rather than depending on the operating system to handle these problems, the task itself must take responsibility for them.

An example program that uses the IDCMP facility to communicate with a window is found in Listing 3-21. After opening a background and a foreground window, this program sets up a read-loop that monitors the IDCMP port. Specifically, it is looking for a CLOSEWINDOW event. The loop is created by using a *Wait()* function to suspend operation, pending the reception of signal. When that occurs, all of the queued-up messages are stripped off through the *GetMsg()* function and properly replied to through *Reply()*. If any of these messages contains a window close request, it is honored.

Listing 3-21. Use of the IDCMP to communicate with an open window.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Window *Wind,*NoBorder;


struct IntuiMessage *mesg;


main()
{
 ULONG flags,iflags,mclass;
 SHORT x,y,w,h;
 VOID delay_func(),OpenALL();

 OpenALL();

  /*  ======Open a borderless window======*/

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|BORDERLESS;
```

Listing 3-21. (cont.)

```
   iflags=NULL;
   NoBorder=(struct Window *)
      make_window(x,y,w,h,NULL,flags,iflags);


   /*   ======Open a plain window=====  */

   x=y=20;
   w=300;
   h=100;
   flags=ACTIVATE|WINDOWSIZING|WINDOWCLOSE|WINDOWDRAG;
   iflags=CLOSEWINDOW;
   Wind=(struct Window *)
      make_window(x,y,w,h,"Window",flags,iflags);

 /* ===Set Up an IDCMP Read Loop ==== */

   Wait(1<<Wind->UserPort->mp_SigBit);

   while((mesg=(struct IntuiMessage *)
      GetMsg(Wind->UserPort))!=NULL)  {
       mclass=mesg->Class;
       ReplyMsg(mesg);
     }
       if(mclass==CLOSEWINDOW)  {
         CloseWindow(Wind);
         delay_func(100);
         CloseWindow(NoBorder);
        }
}
```

The Console Device

There are three methods for putting messages on the display:

1. An image can be directly created by using the graphics primitives built into the operating system kernel. This gives maximum flexibility.
2. Intuition also supplies a similar set of graphics routines, which allow an application to display values and pictures. These routines take responsibility for more of the detail work of creating images. As a result, they are easy to use.
3. If the only output is text, the console device can be used. This displays line-oriented text with all of the features of a traditional terminal display.

We will leave the graphics techniques for a later chapter and turn our attention here to text output.

The console device is the preferred medium for text-oriented output: it

adds the text processing, editing, and formatting capabilities that we have come to expect from a computer terminal. Although this device exists outside of Intuition, it can easily and smoothly interface with a window to produce a pleasing and convenient user interface. There are two ways to activate the console device: as an AmigaDOS device file or directly through calls to the console device.

The AmigaDOS console is the easiest to deal with, although it does involve the most operating system overhead. Under AmigaDOS, a console is treated as a kind of file—a byte stream. It is a sequential file of character strings with no further organization. Another qualification placed on this kind of console concerns the nature of the values. Raw, unprocessed input is one option, but well-behaved ASCII characters can be specified and are the rule. *Open()* is the AmigaDOS function call that sets up and starts the console. A call to the complementary *Close()* will shut it down. Access is equally simple; it, too, is byte-oriented. The controlling task must supply a buffer to hold the input characters and a count of how many are going in or out. Once these parameters are set and the console is opened, access is obtained through an appropriate AmigaDOS function call: *Read()* or *Write()*. This topic will be covered more fully in Chapter 4, which deals with the AmigaDOS operating environment.

More flexibility is available by opening the console device directly, bypassing AmigaDOS. To do this you must access the executive kernel. The first step is to allocate an *IOStdReq* structure, but in this case you need only initialize one of the fields. The *io_Data* field is set with a pointer to the window in question. A call to *OpenDevice()* starts up the console device, connecting it to the specified window. IOStdReq is also set up for communication between these two objects. At this point, text can be sent back and forth between the console and the window.

To read from the console device, the following steps are necessary:

- Set the *io_Data* field of *IOStdReq* to the address of a string buffer.
- Set the *io_Length* field to the number of bytes expected in the transfer operation.
- Finally, put the CMD_READ flag into *io_Command*.

The read will be initiated by one of the I/O functions. *DoIO()* will transmit the request and then halt the task until that request is satisfied. *SendIO()*, in contrast, will transmit the request and then return control to the calling program, even before that request has been satisfied. The field *io_Actual* will contain the number of bytes that were actually transferred.

Text is written to the window in a similar way. The *io_Data* field and *io_Length* field are initiated as before, but this time the buffer contains the message to be sent. The *io_Command* field is set equal to the flag CMD_WRITE. Either *DoIO()* or *SendIO()* begins the request. Text will be written only in the non-border area of the window; it will never overwrite the border gadgets. A line that is too long to fit into the window space will be wrapped around to the next line.

A program illustrating these functions and procedures can be found in

Listing 3-22. Here the function *Send_Message()* is created to properly initialize a IOStdReq structure and use it to send a message.

Listing 3-22. Placement of text in a window using direct control of the console device.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Window *Wind,*NoBorder;


main()
{
 ULONG flags;
 SHORT x,y,w,h;
 VOID delay_func(),OpenALL();

 OpenALL();

  /*  ======Open a borderless window======*/

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|BORDERLESS;
  NoBorder=(struct Window *)make_window(x,y,w,h,NULL,flags);


 /*   ======Open some plain windows=====  */

  x=y=20;
  w=300;
  h=100;
  flags=ACTIVATE;
  Wind=(struct Window *)make_window(x,y,w,h,"Window",flags);

 /* ===Send a message to the window=== */

  Send_Message(Wind,"I'm seeing the world in a window");


 /*   ======Delay for a bit to show off the windows====== */

  delay_func(100);

 /* =========Close down the windows in order========*/

  delay_func(10);

  CloseWindow(Wind);

  delay_func(10);
```

Listing 3-22. (cont.)

```
  CloseWindow(NoBorder);
}


Send_Message(to_window,message)
struct Window *to_window;
UBYTE *message;
{
 struct IOStdReq mesg;

 /* ===Open the console in the window=== */

 mesg.io_Data=(APTR)to_window;
 OpenDevice("console.device",0,&mesg,0);

 /* ===send the message=== */

 mesg.io_Data=message;
 mesg.io_Length=-1;
 mesg.io_Command=CMD_WRITE;
 DoIO(&mesg);

 /* ===tidy up=== */

 CloseDevice(&mesg);

}
```

With the console device comes a full range of control sequences. These sequences offer special formatting and display options that allow the console device to mimic virtually any existing terminal, or allow the user to customize to personal taste. In fact, the entire set of keyboard bindings—the values assigned to each keyboard code—can be altered by an application.

Building an Intuition Library

Our example programs up to this point have relied on our collection of support files: i_sup.o. s_sup.o, and s_sup.o. With a little extra work, these files can serve a more general purpose and form the nucleus of a library of Intuition support functions that will further simplify the way that we write programs for this operating system.

One important facility that is missing from our current collection of support functions is a set of Intuition i/o operations. It would be useful to be able to open a window, collect keyboard input through it, as well as sending our own messages out its display. What would be particularly useful is a pair of functions that would handle the details for us much as print f( ) and scanf( ) handle the details of formatting and data conversion.

One solution to this program is found in Listing 3-23 which shows the contents of w_io.c.

Listing 3-23. Window input/output support routines—w_io.c

```
#include <exec/types.h>
#include <intuition/intuition.h>

#define EOLN            1   /* end of line flag */
#define EOLW            2   /* end of window flag */
#define BACK_SP      0x08   /* interesting keyboard events */
#define CARRIAGE_RET 0x0D

static struct IntuiMessage *msg,*GetMsg();

int Current_x,Current_y;


/* wputs() first moves the cursor to the currect position, then writes the
          character. The current position is found in the variables
          Current_x and Current_y. */

void wputs(window,string)
struct Window  *window;
char *string;
{
 Move(window->RPort,Current_x,Current_y);
 Text(window->RPort,string,strlen(string));
 Current_y+=8;                              /* move to the next position */
}

/*
 wgets() captures several interesting keyboard events occurring
        within the selected window.
*/

wgets(window,string)
struct Window *window;
char *string;
{
 int flag=0;
 SHORT x,y;

 Move(window->RPort,Current_x,Current_y);
 Current_y+=8;

 for(;;) {
  Wait(1 << window->UserPort->mp_SigBit);

  while((msg=GetMsg(window->UserPort)))  {
    if(msg->Class == CLOSEWINDOW)   {   /* user wants to shut down window */
      ReplyMsg(msg);
      flag=EOLW;
      break;
```

Listing 3-23. (cont.)

```
    }
    if(msg->Class == VANILLAKEY)            /* keyboard input */
      if(msg->Code == CARRIAGE_RET) {       /* set end of line flag */
        ReplyMsg(msg);
        flag=EOLN;
        break;
      }
     else
     if(msg->Code == BACK_SP) {      /* user wants to erase characters */
         if(window->RPort->cp_x <= Current_x)  /* can't backup beyond */
            break;                             /* column one */
         string--;
         x=window->RPort->cp_x;
         y=window->RPort->cp_y;
         Move(window->RPort,x-8,y);
         Text(window->RPort," ",1);
         Move(window->RPort,x-8,y);
      }
     else                                      /* simple character input */
       if(window->RPort->cp_x < window->Width-8) {
         *string = msg->Code;
         Text(window->RPort,string,1);
          string++;
       }
   ReplyMsg(msg);
  }
  *string='\0';
  if(flag == EOLN)              /* signal end of line */
    return EOLN;
  if(flag == EOLW) {            /* close window handler */
    CloseWindow(window);
    return EOLW;
   }
 }
}
```

Two complementary functions are defined in this file:

- *wputs()* accepts a character string from the calling program and places it in the specified window.
- *wgets()* will initialize its parameter string with the next line entered through its window.

Both of these functions deal with character strings, but the same principles apply to other kinds of output.

Wputs() is the simplest of the two although it does depend on some system functions that won't be fully covered until Chapter 5. *Text()* will write the supplied text on the screen, while *Move()* will fix the position for this write. Both are graphics-oriented system calls. It should be noted that even the positioning of the imaginary cursor within the window is being handled

by the program. The external variables, Current_x and Current_y contain the information necessary to accomplish this positioning. Using these variables is the simplest way to handle the cursor when dealing with a single window. In the expression Current_y+=8, the figure 8 is a constant value that refers to the font size: it will vary for other fonts.

The input function *wgets()* is a much more complex collection of code. Here we set up an IDCMP port and are set to trap two different classes of events:

- CLOSEWINDOW indicates that the user has clicked this particular gadget in the window border.
- VANILLAKEY is a keyboard event. A basic or raw keycode that has been translated using the default keymap. A simple ASCII value.

Another possibility is to look for a RAWKEY event and do the character conversion explicitly. A CLOSEWINDOW event will cause an immediate exit from the loop, a call to CLOSEWINDOW( ), and a return of an appropriate flag value.

The VANILLAKEY event is further subdivided into three parts. If the user enters a carriage return, an end of line flag is set and this is returned to the calling function. If a user enters a backspace, the character is erased from the display. Note that positioning and erase are handled by the program and not by any operating system buffering routine. Furthermore, a check is made to ensure that the user does not backspace beyond the first column of input. With simple character input, the last code typed at the keyboard is entered into the string. This character is also echoed in the window.

For the functions in Listing 3-23 to work properly, some adjustment to our earlier files must be made. Since even text is rendered by the graphics system within a window, we must alter the *OpenAll()* function in i_sup.c. Now it must open the Graphics library as well as Intuition. This change is reflected in Listing 3-24.

Listing 3-24. New Intuition support routines—i_sup.c

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct IntuitionBase *IntuitionBase;
struct GfxBase *GfxBase;

#define INTUITION_REV 33      /* set the revision number of Intuition */
#define GRAPHICS_REV 33       /* ...and the graphics revision */

/* OpenAll() sets up the intuition environment for the user. */

OpenAll()
{
 IntuitionBase=(struct IntuitionBase *)
           OpenLibrary("intuition.library",INTUITION_REV);

 if(IntuitionBase==NULL)
```

Listing 3-24. (cont.)

```
    exit(FALSE);

 GfxBase=(struct GfxBase *)
           OpenLibrary("graphics.library",GRAPHICS_REV);

 if(GfxBase == NULL)
   exit(FALSE);
}
```

It is also necessary to change the make_window( ) function in w_sup.c and to set the parameters of the IDCMPFlags field to the proper values. We have also made this window function serve another general purpose by adding a provision that allows it to work either with a custom screen or with workbench in Listing 3-25.

Listing 3-25. The modified window support function—w_sup.c

```
#include <exec/types.h>
#include <intuition/intuition.h>

/* make_window() will open a window in the specified screen and with the
                 indicated characteristics. */

make_window(x,y,w,h,name,flags,color0,color1,screen)
SHORT x,y,w,h;
UBYTE *name,color0,color1;
ULONG flags;
struct Screen *screen;
{
 struct NewWindow NewWindow;

 NewWindow.LeftEdge=x;              /* initialize a NewWindow object */
 NewWindow.TopEdge=y;
 NewWindow.Width=w;
 NewWindow.Height=h;
 NewWindow.DetailPen=color0;
 NewWindow.BlockPen=color1;
 NewWindow.Title=name;
 NewWindow.Flags=flags;
 NewWindow.IDCMPFlags=CLOSEWINDOW|VANILLAKEY; /* setup for keyboard input*/
 if(screen == NULL)
   NewWindow.Type=WBENCHSCREEN;
 else {
   NewWindow.Type=CUSTOMSCREEN;
   NewWindow.Screen=screen;
  }
 NewWindow.FirstGadget=NULL;
 NewWindow.CheckMark=NULL;
 NewWindow.BitMap=NULL;
 NewWindow.MinWidth=0;
 NewWindow.MinHeight=0;
```

Listing 3-25. (cont.)

```
 NewWindow.MaxWidth=0;
 NewWindow.MaxHeight=0;

 return(OpenWindow(&NewWindow));   /* return the address of the window */
}
```

Finally, Listing 3-26 contains a simple driver program to test out our new library functions. In this program, we open a high resolution screen and a window inside it. Inside a loop, input is accepted from a window and is immediately echoed back. The program is continuous until the user closes the window by clicking on the Close Gadget. Note that the initial cursor position is set relative to the position of the new window.

Listing 3-26. A program to test the window library functions.

```
#include <exec/types.h>     /* include the support header files */
#include <intuition/intuition.h>

#define EOLN            1   /* end of line flag */
#define EOLW            2   /* end of window flag */
#define BACK_SP      0x08   /* interesting keyboard events */
#define CARRIAGE_RET 0x0D

struct Window *wind;
struct Screen *Scrn=NULL;

extern Current_x,Current_y;
void wputs();
main()
{
 ULONG flags;
 SHORT x,y,w,h,d;
 USHORT mode;
 UBYTE *name,c0,c1;
 char string[80];
 OpenAll();

 /* ======Open a Hi Res Custom Screen==== */

 name="High Resolution Screen";
 y=0;
 w=640;
 h=400;
 d=3;
 c0=0x00;
 c1=0x01;
 mode=HIRES;

 Scrn=(struct Screen *) make_screen(y,w,h,d,c0,c1,mode,name);
```

Listing 3-26. (cont.)

```
 /* =======And a Window==============*/

 name="Window";
 x=20;
 y=20;
 w=300;
 h=100;
 flags=ACTIVATE|WINDOWCLOSE|WINDOWSIZING|WINDOWDEPTH|
                            WINDOWDRAG|SM ART_REFRESH;
 c0=-0x01;
 c1=-0x01;

 wind=(struct Window *) make_window(x,y,w,h,name,flags,c0,c1,Scrn);

 Current_x=wind->BorderLeft+1; /* set initial cursor position */
 Current_y=wind->BorderTop+7;

 while((wgets(wind,string)) != EOLW) /* loop until the user says stop */
   wputs(wind,string);

 CloseScreen(Scrn);
}
```

Not only do these files contain useful functions and routines that will help us in our day-to-day programming, but they also serve as a model for dealing with the complexity of Intuition in a reasonable manner. By using the separate compilation facility of C, we can easily manage the complex data objects which are necessary to get full benefit from the powerful hardware.

A Final Note on Programming Style

The programs in this chapter—as well as those in the rest of the book—were designed primarily to illustrate the elements of the Amiga software environment. Our purpose is to illustrate the methods by which a programmer can access each subsystem and make it perform.

In order to enhance the tutorial nature of each listing, efficiency and explicit error checking are sacrificed for clarity of expression; to include it would have obscured the sometimes intricate methods required by this complex software system. However, the reader should not assume that such considerations, particularly error checking—are in some way optional. On the Amiga, with its multitasking and lack of hardware memory management, it is vital to capture error conditions and return allocated resources; to fail to do so will lead to programs that do not behave well in this sophisticated environment.

Each time a library is opened, or a screen or window created, the system gives up some of its store of free memory to the object. When such objects are

no longer needed, this memory resource must be returned to be used by other executing programs. There is no mechanism to return this memory automatically; the programmer must ensure that his or her code performs this service. It is particularly important when an error condition occurs while several of these items are being opened. If a program fails, some means of graceful shutdown must be included that will ensure that previously created objects will also be closed down.

Another question is one of efficiency. In order to emphasize the parameters of Intuition objects, we have declared appropriate structure variables and then explicitly made assignments to individual members. A more efficient way would be to declare and initialize these structures in one step; this is particularly attractive since many of these values do not change during the run of the program. The examples in our proposed user library conform to this latter rule.

Listing 3-27 is another example of the program found in Listing 3-8; this one includes error checking as well as a more efficient structure. The reader is invited to compare the two programs and note their differences.

Listing 3-27. An example of a complete program.

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <lattice/dos.h>

struct IntuitionBase *IntuitionBase;
struct Window *make_window(),*Wind0,*Wind1;
struct Screen *Scr0,*Scr1,*make_screen();

char high_res[]="High Resolution Screen",
     low_res[]="Low Resolution Screen";

#define ACT      ACTIVATE   /* shorten the flag values */
#define I_REV 33

main()
{

 if((IntuitionBase=(struct IntuitionBase *)
              OpenLibrary("intuition.library",I_REV))==NULL)
          exit(FALSE); /* library failed to open */


/*=====open a hi-res custom screen======*/

 if((Scr0=make_screen(0,640,200,3,00,01,HIRES,high_res))==NULL) {
   CloseLibrary(IntuitionBase);        /* close the library */
   exit(FALSE);                       /* gracefully exit program */
 }


/* ============and a window================*/
```

Listing 3-27. (cont.)

```
 if((Wind0=make_window(20,20,300,100,"Window",ACT,-1,-1,Scr0))==NULL) {
   CloseScreen(Scr0);                    /* Close the open Screen */
   CloseLibrary(IntuitionBase);          /* Clean up the system */
   exit(FALSE);
 }


/*=====open a low-res screen======*/

 if((Scr1=make_screen(50,320,150,3,0,1,NULL,low_res))==NULL) {
   CloseWindow(Wind0);                      /* close the previous window */
   CloseScreen(Scr0);                       /* ...and the screen */
   CloseLibrary(IntuitionBase);             /* close the library */
   exit(FALSE);                             /* gracefully exit program */
 }


/* ============and a window================*/

 if((Wind1=make_window(20,20,150,100,"Window",ACT,-1,-1,Scr1))==NULL) {
   CloseScreen(Scr1);                    /* Close the open Screen */
   CloseWindow(Wind0);                   /* the previous window */
   CloseScreen(Scr0);                    /* ...and screen */
   CloseLibrary(IntuitionBase);          /* Clean up the system */
   exit(FALSE);
 }

 Delay(300);                /* wait a bit to show off the windows */

 CloseWindow(Wind1);       /* close down the windows and screen in order */
 CloseScreen(Scr1);
 Delay(200);
 CloseWindow(Wind0);
 CloseScreen(Scr0);
 CloseLibrary(IntuitionBase);
}
```

Summary

This has been a long chapter and a difficult one to summarize. We have covered the topic of Intuition and its basic operation. This has run the gamut from the very basic notions of screens and windows, through the complex tasks of defining menus and gadgets, to input and output through a window-based operating system, ending up with the system preferences for data structure. We have seen Intuition as a very complicated but very rich operating environment, which repays the extra effort required in programming with a very flexible operating system that allows us to create software that is reliable and, most of all, easy to use.

Process Control and AmigaDOS

Chapter 4

Multitasking
AmigaDOS
Using Workbench To Start a Process
Summary

The Amiga has a traditional operating system, AmigaDOS, which works together with Intuition. The most important task of AmigaDOS is resource management, including not only the file management system, but the all-important multiprocessing system. In this chapter, we'll discuss the use of this operating system resource to create programs that run successfully in an environment with other executing processes.

Multitasking

Most large computers—in contrast to the ubiquitous microcomputer, which has become almost a fixture in our daily lives—are scarce resources. In order to use them, you must schedule time, make a reservation for a terminal period, or even submit a program to be run. Every effort has been expended to wring the last bit of operating time out of them. To this end, these systems are invariably multitasking: they run more than one program at a time. Indeed, they are more than this; they are also multi-user, serving more than a single user at a time.

Until recently, microcomputers have not been treated in quite the same way. Because of their origin as small, general purpose machines, many of these machines have correspondingly simple operating systems. Usually, they can run only a single program at a time. Attempts have been made to create an environment in which more than one program can be in memory, but even then only one of these programs is available to the user at any given time. Switching from one to the other can be quite awkward.

The advantages of multitasking are obvious: an increased productivity in terms of number of tasks performed per unit of time. If I can run two or three programs at the same time on my computer, I can accomplish more than if I can only run one. The trade-offs may not be so obvious, however. It is not just that a multitasking operating system is more complex than a single-user system. If this were the only difference, we would have long ago

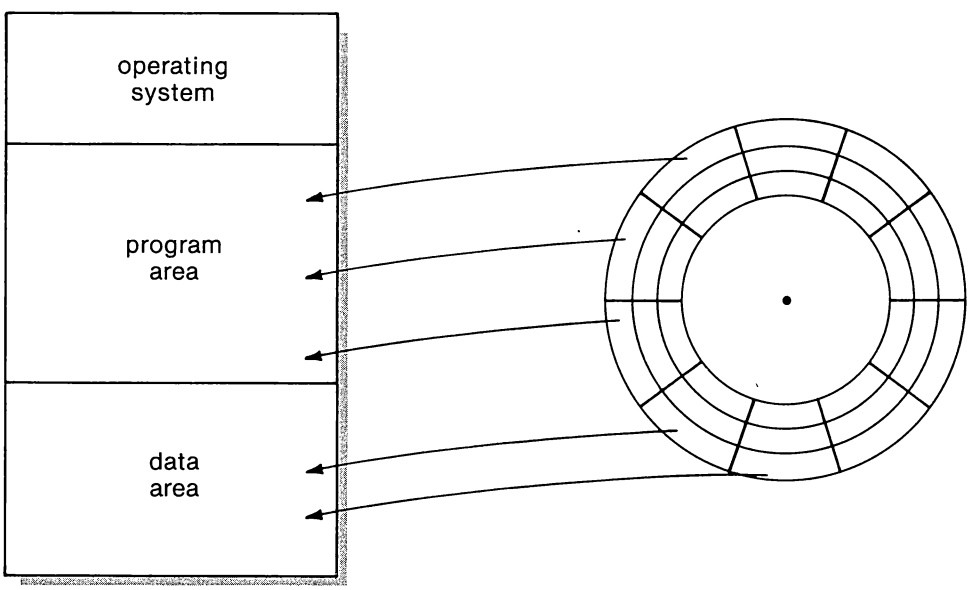
seen such operating systems dominate the small computer market. The complexity of multitasking also requires hardware support: increased memory and speed of computation—things that have only recently become available for a reasonable price in small computers.

The Amiga is an ideal machine to implement this more complex system software. It has a powerful and fast microprocessor chip, capable of addressing up to 8 million bytes of memory, coupled with a set of specialized processors that ease the burden of the main CPU, leaving plenty of time for it to do the housekeeping associated with multitasking.

The Process

Most of us are used to thinking of the program as the main object of attention in a computer. We write it, compile it, swear over it, and finally, run it. This is a perfectly adequate view when dealing with a single-tasking system. The compiled program consists of a series of executable machine commands—numbers that represent instructions for the CPU or that identify locations in memory where data is stored. The object file is really an image of the memory when the program runs. Loading the program is a process of copying from the disk directly into memory. Since there is only one program, it is always loaded at the same place (Figure 4-1). Program execution is begun by a jump command to that location.

Figure 4-1. A single processing system



Code and data are always loaded at the same location.

This description is accurate, if a little bit simplistic. The situation is complicated by many factors, including the presence or absence of co-resident programs. These are usually loaded in memory away from the area occupied by the main program, frequently at the other end of the computer's address space. Space must be left for the operating system utilities and service routines.

In contrast, a multitasking system's program loading and memory management are more difficult. More than one task is going on at the same time, and if we wish to load a new program, where we put it is a function of which memory locations are available. It doesn't always go into the same spot. Starting the program up is also a more complex process; we can no longer rely on a simple jump command to accomplish the job.

On the Amiga—as in most multitasking environments—rather than a static landscape of memory locations, we have a more fluid situation. The resources in use and those available are in a constant state of flux. First one set of instructions is executed; then, when these are blocked (perhaps waiting for keyboard input), attention is focused on some other set of commands. You need a way to make sense out of this constant switching. You need something, too, that describes how a program is loaded and run (Figure 4-2).

In a broad sense, a program bears the same relationship to a process as the program's executable code does to the source statement that was used to produce it. A single program can give rise to many processes. Each process is an independent example of the program executing in its own memory locations, using its own resources. It is the process and not the program that is manipulated by the operating system.

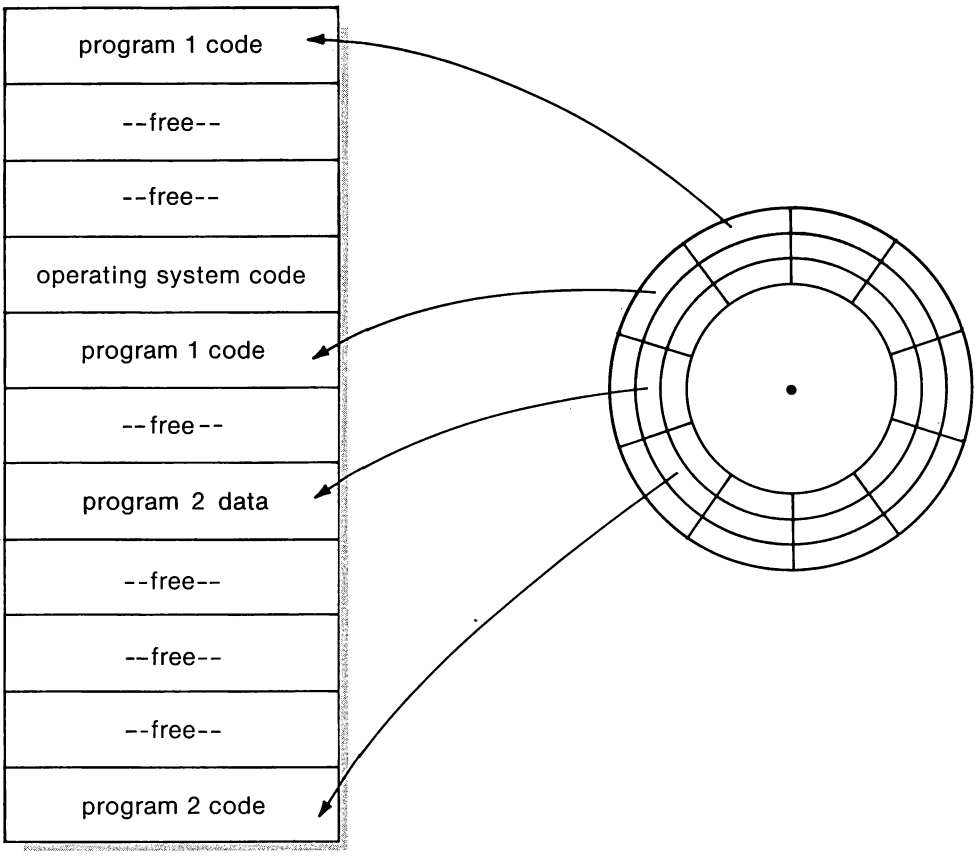
A *process*, then, is an entity that lives in memory. When you or one of your programs decides to run a program, a process is spawned. When it has finished doing its job, it is removed and another one takes its place. A program can give rise to many processes because you can load the code in different locations and start it up independently. It is important to maintain this distinction between program and process.

As stated above, a process is a program—or anyway a collection of executable code—that is in the process of executing. During its time in the memory, this process must interact not only with the operating system itself, but also with other processes, both competing and cooperating. Some of these processes are put in place by the operating system itself. There is a process to control the disk drive, a process to handle output to the printer, and even one to accept keyboard input. This ability to interact is what makes a multitasking operating system convenient and powerful.

Messages

How do processes interact? What allows them to cooperate with one another and with the operating system? All of this is accomplished through the use of an elaborate message passing system. When a process is started up, the specific resources called for in the program code itself are allocated, as well as

Figure 4-2. A multiprocessing system



Program code and data are loaded at different locations in the memory.

system specific resources. The most important of these is a port that allows communication with the outside world.

The most basic underlying system software, the executive kernel, maintains a message passing system that all processes can and must use for communication (Figure 4-3). The key to this system is twofold:

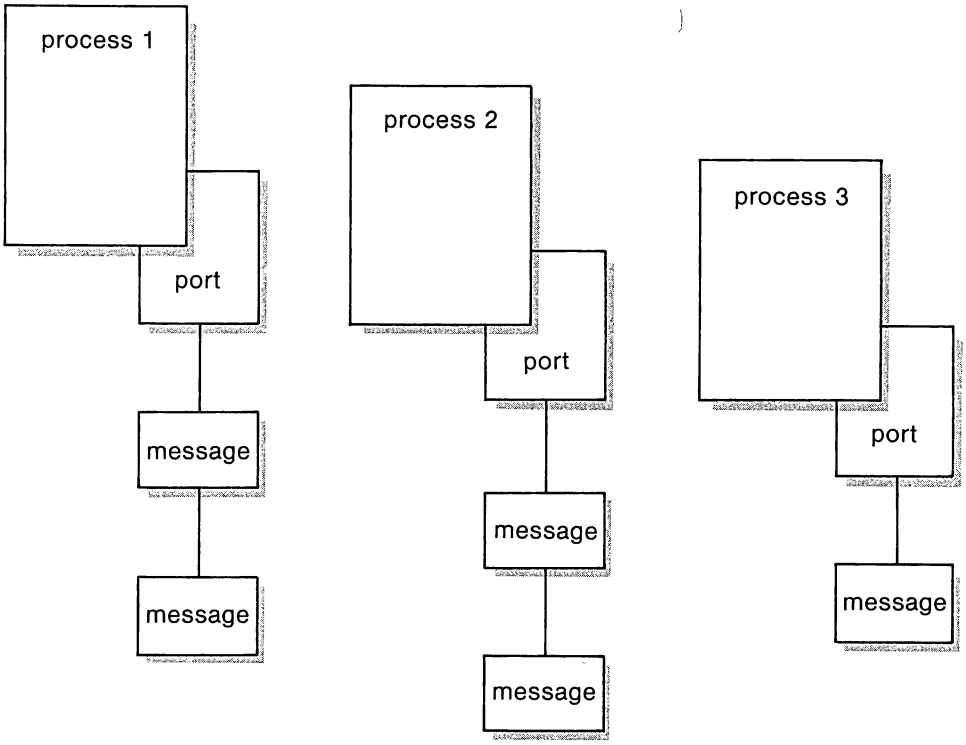
- A port associated with each process that sends and receives
- The messages themselves

Because this system is maintained at the lowest level of the machine—even lower than AmigaDOS or Intuition—there is a consistent interface among system resources that greatly simplifies programming.

The message consists of two main parts:

1. A section that contains the hooks that allow the executive to manipulate the message

Figure 4-3. The message-passing system



2. The body of the message, which contains the actual values to be transmitted

The former is consistent throughout all levels of system software, while the latter is specific to the problem at hand and may be vastly different for different contexts.

The message object is implemented as a C structure; it has the general form:

```
struct Message {
   struct Node mn_Node;
   struct MsgPort *mn_ReplyPort;
   UWORD mm_Length;
};
```

where

mn_Node is an object that supplies the system connections mentioned above.

mn_ReplyPort is a pointer to the port where the sender expects a reply.

mm_Length indicates the size of the message body.

This message structure becomes the preface messages that are created for specific situations. For example, consider the following message form:

```
struct P_message }
   struct Message p_mess;
   UBYTE *line;
};
```

This allows you to send a character string as a message to a printer or other display device. The system-wide message structure allows you to tap into the operating system's message handling software—its "switchboard"—but the specific parts of the message allow you to tailor it to your own requirements. Of course, this is a simple example. There is no restriction on the complexity of a message structure.

Ports

Once you have defined your messages and put them into a useful form, you must have somewhere to send them. You need to have a specific way to address both source and destination. Keep in mind that the Amiga is a "software driven" machine. System routines and, more important, devices are not hard wired into the memory, but are loaded at various locations, which may change between runs or in the course of running a series of programs. For each object in this web of communication, you must define one or more ports.

A *port* is a multifaceted object that serves as a connecting link between communicating processes. Whenever you send a message, you include the address of a *reply port* in the body of the message. This represents the location where you expect some kind of communication from the recipient object—a reply, for example, that the message was received.

Like the message, the port is implemented as a software object and is accessed through a C structure data type. The specific form of this structure is:

```
struct MsgPort  {

   struct Node     mp_Node;

   BYTE            mp_Flags,

                   mp_SigBit;

   struct Task     *mp_SigTask;

   struct List     mp_MsgList;
}
```

where

mp_Node creates a linked data structure for this object.

mp_Flags indicates what is to be done when a message arrives:
PA_SIGNAL, signal a particular task.
PA_SOFTINT, perform an interrupt.
PA_IGNORE, ignore the arrival.

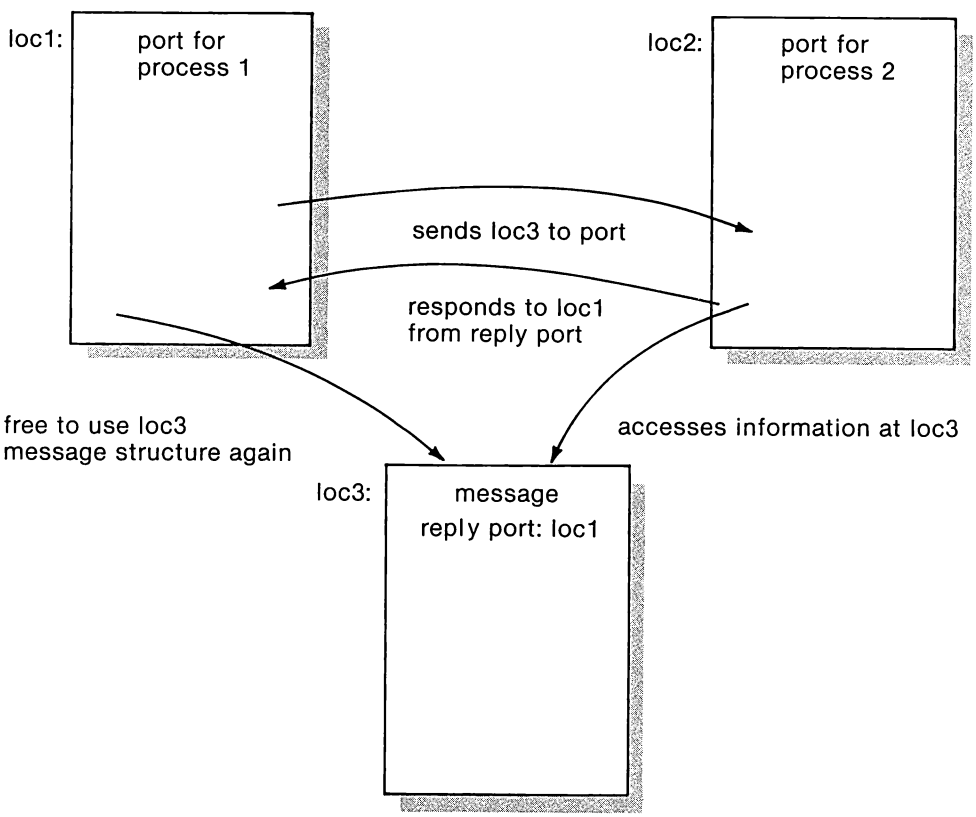
mp_SigBit identifies a specific signal when signaling is enabled.

mp_SigTask points to the task that is to be awakened by the signal or interrupt.

mp_MsgList is a header pointing to the queue of messages that have arrived.

Unlike the message structure, except at the very lowest levels, this structure tends to be manipulated via system routines and not directly. In operation, the port—or more properly, the *mp_SigTask* member of the port—acts as head of a linked list of messages waiting to be served by whatever device or process contains the port. These messages are collected as they arrive to form a FIFO (First In First Out) queue; they are then handled in the order received. Figure 4-4 illustrates the relationship between ports and messages.

Figure 4-4. The relationship between ports and messages



What is actually being transmitted when a message is sent between two operating system entities? How is this connection made? This can be confusing. The only thing that does any traveling is a memory address. When you send a message from process A to device B, you create the message structure in that part of memory allocated to A and then pass a pointer to this structure to B. You are implicitly giving B the means and the right to access and probably change part of A's memory. As a result, it is important that A not alter the structure until B signals that it has received the message. Nothing has been transmitted in the sense of a telephone line or a radio signal—a common but misleading metaphor used to explain message passing systems—just a reassignment of values, in this case, address or pointer values.

A *port address* is frequently sent as part of a message. This is the reply port and it has a specific function to fulfill. The receiving entity—process or device—must tell the sender that the message was received. This acknowledgment is directed to the reply port found in the message structure. However, it is also possible and sometimes desirable to have a port that is publicly available. This is accomplished by giving the port a name which can later be accessed by other processes. This access is via the name field as part of the *mp_Node* field within the message port structure.

Manipulating Ports and Messages

The executive kernel contains a variety of system functions to manipulate ports and messages. You can add ports to the system and remove them using *AddPort()* and *RemPort()*. You can even use *CreatePort()* to generate a brand new port—although this is not, strictly speaking, a system function, but is supplied as part of a library. The main interest in this chapter, however, centers around the use of this message passing system: how to send and receive messages.

The appropriate functions that allow you to use the facilities of the message passing system are listed below.

```
port_id=FindPort(name)
```

where

port_id is a pointer to a port in the message system.

name is a character string containing the port name.

This function returns a pointer to a publicly accessible, named port.

```
PutMsg(port_id,message)
```

where

port_id is a pointer to a port.

message is a pointer to a message structure.

This function sends a message to the designated port.

```
message=GetMsg(port_id)
```

where

port_id is a pointer to a port.

message is a pointer to a message structure.

This function removes the next message on the port's queue.

```
ReplyMsg(message)
```

where

message is a pointer to a message structure.

This function returns a message to its point of origin.

```
message=WaitPort(port_id)
```

where

message is a pointer to a message structure.

port_id is a pointer to a port.

This function suspends a calling process until a message is returned.

PutMsg() sends an initialized message structure to a particular port. The execution of this function is asynchronous: once it is called, any action performed by the operating system is done independently of the calling program. Since the Amiga has a multitasking operating system, responsibility for carrying through on this command is left to another process. The net effect is that control immediately passes to the next statement in line.

Receiving a message is a more complex process. First, you have to know that a message has arrived at a given port. This requires an effort of synchronization between the sender and the receiver. The executive kernel has a signal allocation system to supply this synchronization. Furthermore, there is a high-level system that allows you to tap into it. The *WaitPort()* function puts the current task to sleep until a signal reaches its port.

Once you know that a message is waiting for you, you still have to remove it from the port's queue; this is done with the *GetMsg()* function. Each call of this function removes the next message from the port. Note that these messages come off their queue in FIFO order; no other form of priority scheme can be applied to them. If there are no messages available, the value zero is returned.

Finally, it is frequently, if not usually, the case that once a message is received, it must be acknowledged to the sender. This is accomplished using the *ReplyMsg()* system call. *ReplyMsg()* returns the message structure to the

port mentioned in the *mm_ReplyPort* of this original data structure. If the field is set to zero, no reply is expected. *ReplyMsg()* returns the original message, so it must not be called until that message has either been acted on or copied to a local buffer. By returning the message, you lose control of it. Messages are frequently reused by processes, so even if you retained its address, you would have no guarantee of the integrity of the values you found. Before a message is answered, it is the property of the receiver. Of course, you must return the message as soon as possible, in order to speed up total system operations and increase process execution.

A kind of message receiving template is defined by the following code fragment;

```
WaitPort(Port);
While((message=GetMsg(Port))!=NULL) {
   ==>do something with the information<==
   ReplyMsg(message);
}
```

The basic command sequence appears over and over again in example programs. It illustrates the way you can use these system calls to produce coordinated message exchanges. Of course, *PutMsg()* would be initiated from the original calling process.

These four system functions—*PutMsg()*, *GetMsg()*, *WaitPort()*, and *ReplyMsg()*—are used in concert to access the message passing software made available by the executive kernel. They allow software objects not only to communicate with one another, but also to synchronize their operations. It must be emphasized that these are not the only system functions available to the user. These are the ones you will use to implement and control multitasking under AmigaDOS, but several other low-level subsystems are available to the advanced user. An entire I/O subsystem, for example, is built on top of this message passing facility; we have already seen examples of this in the earlier chapter on Intuition, particularly in the discussion of window input and output. The next step is to relate messages, ports, and processes. A process, as defined so far, is an independent piece of program code, loaded into memory. It must have some way of communicating with other processes and the outside world. The message passing subsystem supplies this venue. This capability is an important constituent of the Amiga's multitasking capability.

AmigaDOS

Of the three semi-autonomous operating environments available on the Amiga—the executive kernel, Intuition, and AmigaDOS—it is the latter that you will be primarily concerned with in creating multitasking programs. Indeed, it is within AmigaDOS that the notion of a process is formed. These other two operating systems lend support and background services, but the tools needed to create a multiprogram environment are found in AmigaDOS.

The executive kernel supplies the underlying software support for process creation. It defines the message passing system and also a management system for low-level tasks. Each task is a software object that can be created or removed by the operating system. These tasks can be further manipulated, and themselves represent executable code modules. However, a task is not a process; it is a much more primitive entity. These are only the barest beginnings of a multitasking system.

An AmigaDOS process is, like most Amiga software objects, defined by a C structure definition:

```
struct Process {
   struct Task pr_Task;
   struct MsgPort   pr_MsgPort;
   WORD             pr_Pad;
   BPTR             pr_SegList;
   LONG             pr_TaskNum;
   BPTR             pr_StackBase;
   LONG             pr_Result2;
   BPTR             pr_CurrentDir,
                    pr_CIS,
                    pr_COS;
   APTR             pr_ConsoleTask,
                    pr_FileSystemTask;
   BPTR             pr_CLI;
   APTR             pr_ReturnAddr,
                    pr_PktWait,
                    pr_WindowPtr;
};
```

This is a long and complex definition, but fortunately, most of these fields are set by the AmigaDOS system calls that you make to set up and use a process. One important thing that you can see immediately is that a process has a message header for access to the system of ports and messages. Also note that a process is also part of the task manipulation system; entry here is via the Task structure at the very beginning of the definition.

The remaining fields are, for the most part, straightforward, if not always obvious. The *pr_SegList* points to the memory locations where the process code currently resides. *pr_StackSize* indicates the number of bytes in this resource. Process identification is through *pr_TaskNum*; this relates the process to a task number relative to the calling CLI. There are also hooks to the current disk directory (*pr_CurrentDir*), the standard input and output for this process (*pr_CIS* and *pr_COS*), as well as pointers to the various subsidiary and support processes and functions. These fields are rarely manipulated directly by a user process.

The tasking system is responsible for the process once it is in memory. It manages the CPU and other resources. This system takes primary responsiblity for scheduling and moving between the various states associated with an executing process. One of its primary jobs is to switch between the various competing processes, giving each one a quantum of access to the system and then moving to the next. It is this switching that allows many programs to run simultaneously.

Although the tasking subsystem is directly available to the programmer through the executive kernel, it is not necessary to access it to accomplish multiprocessing operation. Direct access to these low-level routines has advantanges and disadvantages. The most important benefit is one of speed. By accessing the tasking system directly, you eliminate the overhead inherent when going through AmigaDOS. Furthermore, direct access gives you routines that are unique to your particular application and not general purpose ones. The disadvantage is that the application itself must handle all of the details of operation; the benefits of dealing with a high-level construct such as a process are lost. In a complex application this can pose a problem.

Calling AmigaDOS

Calling an AmigaDOS function from a C application is a simple procedure. You simply treat the system call that you want as any other C function. You invoke its name, pass it whatever parameters it expects, and take whatever return value it wants to give you. From the programmer's point of view, a system function is really no different from any of the other built-in functions found in the various C libraries.

Listing 4-1 shows a simple call to an AmigaDOS function. In this case, we are accessing the system clock to extract the date and time. The function that we are interested in is:

```
DateStamp(d_ptr);
```

Once called, this function will accept a pointer to a *Datestamp* structure; it will fill this structure with current values:

d_ptr->ds_Days indicates the number of days since 1 January 1978.

d_ptr->ds_Minute is the number of minutes since midnight.

d_ptr->ds_Tick is the number of ticks since the beginning of the minute.

This latter measure is potentially confusing; it refers to a measure that divides a single minute. In the case of the Amiga, there are 50 ticks in a single minute.

Listing 4-1. DateStamp AmigaDOS call.

```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>
```

Listing 4-1. (cont.)

```
main()
{
   struct DateStamp v;

   DateStamp(&v);

   printf("days (since 1/78).............%ld\n",v.ds_Days);
   printf("minutes (since midnight).......%ld\n",v.ds_Minute);
   printf("ticks (from start of minute)...%ld\n",v.ds_Tick);
}
```

DateStamp() is an example of an AmigaDOS system call. It does not directly participate in any multitasking, although it is an important function in its own right, but it does serve to illustrate the calling sequence. Remember, too, the discussion in Chapter 2. In calling AmigaDOS functions, you must link the source code to *amiga.lib* rather than *lc.lib*, and it is imperative that you disable stack checking with the *-v* option. The complete explanation is found in Chapter 2.

Calling Processes from the CLI

If Intuition is the user interface, then the CLI or command interpreter is the programmer's interface. Most program development proceeds from this familiar TTY-like interface. Editors and compilers work from it, and it gives access to most system support utilities. The CLI is perhaps the easiest environment within which to run programs. You have seen in Chapter 3 the many details that must be attended to in writing applications for Intuition. In the CLI, the program interface is familiar and straightforward.

Any program that you run under these circumstances is really a daughter process to the CLI from which you begin. Such processes inherit input/output streams and windows from the parent although they can open their own resources as well. These daughter processes are started up and the CLI goes dormant until the executing process is finished; then it takes control again. The same thing is true for processes spawned by other processes within this environment. Process A begins process B, and then goes to sleep until process B is finished executing.

One way to accomplish this simple form of multiprocessing is to use the *Execute()* system call. The general form of this function is:

```
Execute(string,input,output);
```

Here, the function returns a boolean value to indicate whether or not it was successful. It takes as parameters:

- A string indicating the name of the program to be run
- Input and output streams to be used to display results

If you set input and output to zero, the current assignments for these files is used.

Listing 4-2. A simple example of the AmigaDOS Execute call.

```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>

main()
{

   Execute("dir df1:source",0,0);

}
```

A very simple use of *Execute()* is illustrated in Listing 4-2. Here you have a *main()* function whose sole purpose is to call this function to execute a *dir* command on a particular subdirectory. The function is set up so that it uses the current window as output; there is no input value. Listing 4-3 shows a slight variation on this same program. Here we call two different commands from *main()*. We also program a delay into the program by reference to the *Delay()* system call. This accepts a duration, measured in ticks, as a parameter and waits the specified time.

Listing 4-3. A simple example of the AmigaDOS Delay call. It is used in conjunction with the Execute call.

```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>

main()
{
```

Listing 4-3. (cont.)

```
    Execute("dir df1:source",0,0);

    Delay(1500);

    Execute("info",0,0);

}
```

The *Execute()* system function can be used in the manner illustrated in Listing 4-4. By passing the function an empty string, you can create a new interactive CLI just as if you had called NEWCLI from the command level. In order to accomplish this you must specify a window for the new CLI. The example does this with the declaration:

```
struct FileHandle *wind;
```

This filehandle type will be explained in greater detail in Chapter 9, when we turn our attention to the file management system. Accept it here as a designator for a new input window. By setting the final parameter to zero, the output stream will be associated with this new window.

Listing 4-4. This program starts a new CLI, using the Execute() function.

```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>

struct FileHandle input;


main()
{
  static char cmd[]="";

    Execute(cmd,&input,0);

    Delay(1500);


}
```

Using Workbench To Start a Process

You are now familiar with Workbench from the recent discussion of Intuition. The Workbench Screen is one of the standard screens that comes up in this user interface. In some ways, it is the primary standard screen, certainly the most commonly seen. But Workbench is also a system utility program that defines other operating environments. That's what we will explore here.

Actually, Workbench defines two environments:

1. The iconic interface that allows you to choose programs visually via the mouse and an Intuition screen
2. An interface that allows you to start up programs as complete independent processes

It is this latter capability that is most interesting here, for you can tap it from the CLI interface, bypassing Intuition. Workbench allows you to create the most complete form of multiprocessing—totally independent executing processes.

Before plunging into examples, consider what is necessary to set up an independent process:

1. First, you must load the code that is to execute into the memory of the computer.
2. Second, you must alert the system that you are starting up a new process.
3. You must signal the loaded and initialized code that it can begin executing.

The first of these requirements is self-evident. You cannot run anything until it resides in memory. Configuring code as a process involves taking care of all overhead that is necessary for the system to treat the program as a process. This includes activities such as putting the program in the process queue and initializing its process structure values. Finally, the code itself needs some kind of indication that all is well and that it can begin doing whatever it was meant to do.

Loading program code into memory is controlled by two complementary AmigaDOS functions: *LoadSeg()* and *UnLoadSeg()*. The first of these takes the object file produced by the compiler and linker and loads it into whatever free locations it finds in memory. It has the general form:

```
segment_id=LoadSeg(file_name);
```

Segment_id points to the head of a chain of segments that contains the code. *File_name* is the name of the file as it appears in the disk directory. Note here that the program will not necessarily reside in contiguous memory locations. This is why the *segment_id* is a pointer to a linked list. Once you are finished with the program, you must remove it from memory and return its resources to the free memory pool. This is accomplished by:

```
UnLoadSeg(segment_id);
```

Segment_id points to a linked list of locations to be returned to the system. It is very important to perform these un-do operations. Under AmigaDOS, no automatic reclamation of resources is performed. If you forget to unload memory, it remains unavailable to the system.

Now that you have your program code loaded, you need to turn it into a process. Do this with:

```
process_id=CreateProc(proc_name,pri,segment_id,stack);
```

This system call takes the code that is stored under *segment_id* and creates a new process. *Pri* sets the priority of the process. The value *stack* sets the size of this resource. *Proc_name* is a character string variable that contains a name for the process. *CreateProc()* returns a *process_id* which is of type struct *Process*. If the operation fails, zero is returned.

CreateProc() actually starts up the process. It puts in any necessary queues, does all the overhead necessary to start the process up, and enters the code at the first segment. This segment is expected to contain some initialization routine to get the program started. The easiest way to accomplish this start-up task is to arrange your code so that it accepts a start-up message from its initiating task. Using the Workbench environment and, more specifically the Workbench start-up message, is a very convenient way to accomplish this.

The Workbench start-up message is a software object defined by the structure *WBStartup* found in *workbench/startup.h* shown below.

```
struct WBStartup  {

   struct Message   sm_Message;

   struct MsgPort   sm_Process;

   BPTR             sm_Segment;

   LONG             sm_NumArgs;

   char             *sm_ToolWindow;

   struct WBArg     sm_ArgList;

}
```

where

sm_Message is an entry to the message passing system.

sm_Process connects the start-up message to a process.

sm_Segment points to the memory resident code of a process.

sm_NumArgs indicates the number of arguments being passed.

sm_ToolWindow is a pointer to support window.

sm_ArgList contains the arguments being passed in this message.

Many of these fields relate to the iconic interface. In our examples, we will only be using this structure as a start-up message and so will do the barest minimum of initialization. You should know that there is much more versatility built into this interface than we will utilize now.

Listings 4-5 and 4-6 illustrate a simple process creation. The first program loads the object code from the second, creates a process, sends it a start-up message, and then sends it an additional message with more instructions. The first process then goes to sleep until the second is finished. In Listing 4-6, the program receives the message, executes the request, and then sends a reply message back to the first. This example illustrates one of the simplest systems, where a process spawns another process.

Listing 4-5. A simple process creation, using LoadSeg(), UnloadSeg(), and CreateProc().

```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>

#include <workbench/startup.h>

extern struct Message *GetMsg();
extern int LoadSeg();
extern struct MsgPort *CreateProc();

struct P_Mess  {
   struct Message message;
   char *title;
   int files[3];
 };

extern int stdin;
extern int stdout;
extern int stderr;

struct MsgPort *NewProc;
int NewSeg;

main()
{
 struct Message *reply;
 struct Process *o_proc;

 struct WBStartup st;
 struct P_Mess pmes;
```

Listing 4-5. (cont.)

```
 struct MsgPort *o_rp;

 if(init_proc("p1_test","New Process")==0)
   Exit();

 o_proc=(struct Process *)FindTask(0);
 o_rp=&o_proc->pr_MsgPort;

 make_startup(&st);
 PutMsg(NewProc,&st);

 make_message(&pmes,"CON:100/10/320/150/New Process");

 PutMsg(NewProc,&pmes);

 WaitPort(o_rp);

 reply=GetMsg(o_rp);
 WaitPort(o_rp);
 reply=GetMsg(o_rp);

 UnLoadSeg(NewSeg);

}

init_proc(fname,pname)
char *fname,*pname;
{

   if((NewSeg=LoadSeg(fname))==0)  {
      printf("Can't Create a Segment\n");
      return(0);
    }

   if((NewProc=CreateProc(pname,0,NewSeg,5000))==0)  {
      printf("Can't Create a Process\n");
      UnLoadSeg(NewSeg);
      return(0);
    }
   return(1);
}

make_startup(x,reply_port)
struct WBStartup *x;
struct MsgPort *reply_port;
{
    x->sm_Message.mn_ReplyPort=reply_port;
    x->sm_Message.mn_Length=sizeof(struct WBStartup);
    x->sm_Message.mn_Node.ln_Name="startup";
    x->sm_ArgList=NULL;
    x->sm_ToolWindow=NULL;
}
make_message(y,gist_of_it,reply_port)
struct P_Mess *y;
```

Listing 4-5. (cont.)

```
char *gist_of_it;
struct MsgPort *reply_port;
{
    y->message.mn_ReplyPort=reply_port;
    y->message.mn_Length=sizeof(struct P_Mes);
    y->message.mn_Node.ln_Name="p0_test";
    y->title=gist_of_it;
    y->files[0]=(int)stdin;
    y->files[1]=(int)stdout;
    y->files[2]=(int)stderr;
}
```

First, look at Listing 4-5, the parent process. The required initialization is taken care of by three functions. The first, *init_proc()*, loads the daughter process code into memory and transforms it into a process. The example uses a stack size of 5000 bytes and an arbitrary priority of 0. *Pname* contains the name of the process, but the more important process is contained in the global variable *NewProc*. Once the new process is created, you are ready to set up the communication links between it and its parent. First you must find the reply port attached to the current process. *FindTask()* is a function that returns process identification if you pass it the process name. If zero is passed, it returns the current process. Once you have the process, it is easy to grab hold of the message port. These jobs are accomplished in the example by the lines:

```
o_proc=(struct Process *)FindTask(0);
o_rp=&o_proc->pr_MsgPort;
```

The next step is to utilize this information by passing some messages to the new process.

The *make_startup()* function initializes the WBStartup structure to contain the start-up message. There are no surprises here. The reply port and the size are initialized and the name of this message is set to "startup". Everything else is set to NULL. Back in the *main()* function, we use *PutMsg()* to send the message to its intended recipient.

Finally, *make_message()* is invoked to create a command message to the child process. Again you must initialize the reply port and the size of the message, and give it a name. The actual information that you want to transmit to the other process is contained in the character string "title". Once you have initialized this message, send it again using *PutMsg()*, but this time put the program to sleep with a *WaitPort()*.

Clean-up consists of removing the returning message from the queue with a *GetMsg()*, another *WaitPort()* and another call to *GetMsg()*. In the first instance, you are waiting for the return of the start-up message; the second wait is for a reply to the command message. Finally, you unload the new process segment.

Listing 4-6. A simple process, using LoadSeg(), UnloadSeg(), and CreateProc(). This is the companion to p0_test.c.

```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>
#include <workbench/startup.h>

extern struct Message *GetMsg();
extern struct Task *FindTask();
extern struct FileHandle *Open();

struct P_Mess  {
   struct Message Message;
   char *title;
   int files[3];
 };

extern int stdout;
extern int stderr;

main()
{
  struct P_Mess *pmes;
  struct MsgPort *cur_rp;
  struct Process *cur_proc;
  struct FileHandle *new_outp,*stdin;
  char ch[40],*get_string();

  cur_proc=(struct Process *)FindTask(0);
  cur_rp=&cur_proc->pr_MsgPort;

  WaitPort(cur_rp);

  pmes=(struct P_Mess *)GetMsg(cur_rp);

  stdout=pmes->files[1];

  if((new_outp=Open(pmes->title,MODE_NEWFILE))==0)  {
    ReplyMsg(pmes);
    exit(0);
   }
  else  {
    stdout=(int)new_outp;
    stdin=new_outp;
    printf("enter anything==>");
    get_string(stdin,ch);
    printf("%s\n",ch);
    stdout=pmes->files[1];
```

Listing 4-6. (cont.)

```
    Close(new_outp);
    ReplyMsg(pmes);
   }
}

char *get_string(fp,buffer)
struct FileHandle *fp;
char *buffer;
{
 int len;

 len=Read(fp,buffer,39);
 buffer+=(len+1);
 *buffer='\0';
}
```

Listing 4-6 contains a simple program. It, too, figures out the address of its own port and waits for a message from the parent process. Note that the activity of the start-up message has already been handled by the time these statements are executed. A reply has already been sent. This program is waiting for the second command message. Once the second message is received, it is executed by the statement:

```
new_outp=Open(pmes->title,MODE_NEWFILE);
```

This statement—embedded in an *if* statement—opens the window indicated in the character string *pmes->title*. Although the new process does not inherit any I/O streams from the parent—it is a totally independent process—we do send over the *stdin* and *stdout*. Here we are creating a new set of I/O streams. Once we do this, we ask for some input from the keyboard, then return to the other process.

The finishing code for this smaller process is correspondingly simple. We close the new window, reply to the command message, and then stop execution. One final note—since we are using *amiga.lib* and not *lc.lib*, it is necessary to create *getstring()* in order to do simple input from a window. We do not have *scanf()* available to us in this particular library.

The two remaining examples are variations on this first pair of programs. Listing 4-7 contains a more realistic version of Listing 4-5; it uses *AllocMem()* to dynamically allocate memory and does some additional error checking. Listing 4-8 is, however, significantly different. Here we start up two independent processes from the parent. Each daughter process is given a slightly different command message. Both of these programs use the code in Listing 4-6 to produce child processes.

Listing 4-7. A more complex process creation, using LoadSeg(), UnloadSeg(), and CreateProc().

```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>

#include <workbench/startup.h>

extern struct Message *GetMsg();
extern int LoadSeg();
extern struct MsgPort *CreateProc();

struct P_Mess  {
   struct Message message;
   char *title;
   int files[3];
 };

extern int stdin;
extern int stdout;
extern int stderr;

struct MsgPort *NewProc;
int NewSeg;

main()
{
 struct Message *reply;
 struct Process *o_proc;

 struct WBStartup *st;
 struct P_Mess *pmes;

 struct MsgPort *o_rp;

 if(init_proc("p1_test","New Process")==0)
   Exit();

 o_proc=(struct Process *)FindTask(0);
 o_rp=&o_proc->pr_MsgPort;

 if((st=(struct WBStartup *)
    AllocMem(sizeof (struct WBStartup),MEMF_CLEAR))!=0)  {

    make_startup(st);
    PutMsg(NewProc,st);
```

Listing 4-7. (cont.)

```
  }
 else  {
   FreeMem(st,sizeof(struct WBStartup));
   Exit();
  }

 if((pmes=(struct P_Mess *)
    AllocMem(sizeof(struct P_Mess),MEMF_CLEAR))!=0)  {

    make_message(pmes,"CON:100/10/320/150/New Process");

    PutMsg(NewProc,pmes);

    WaitPort(o_rp);

    reply=GetMsg(o_rp);
    WaitPort(o_rp);
    reply=GetMsg(o_rp);
   }

   UnLoadSeg(NewSeg);

   FreeMem(pmes,sizeof(struct P_Mess));
   FreeMem(st,sizeof(struct WBStartup));
}

init_proc(fname,pname)
char *fname,*pname;
{

   if((NewSeg=LoadSeg(fname))==0)  {
      printf("Can't Create a Segment\n");
      return(0);
    }

   if((NewProc=CreateProc(pname,0,NewSeg,5000))==0)  {
      printf("Can't Create a Process\n");
      UnLoadSeg(NewSeg);
      return(0);
    }
   return(1);
}

make_startup(x,reply_port)
struct WBStartup *x;
struct MsgPort *reply_port;
{
    x->sm_Message.mn_ReplyPort=reply_port;
    x->sm_Message.mn_Length=sizeof(struct WBStartup);
    x->sm_Message.mn_Node.ln_Name="startup";
    x->sm_ArgList=NULL;
    x->sm_ToolWindow=NULL;
}
make_message(y,gist_of_it,reply_port)
```

Listing 4-7. (cont.)

```
struct P_Mess *y;
char *gist_of_it;
struct MsgPort *reply_port;
{
    y->message.mn_ReplyPort=reply_port;
    y->message.mn_Length=sizeof(struct P_Mes);
    y->message.mn_Node.ln_Name="p0_test";
    y->title=gist_of_it;
    y->files[0]=(int)stdin;
    y->files[1]=(int)stdout;
    y->files[2]=(int)stderr;
}
```

Listing 4-8. The creation of two processes.

```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>
#include <workbench/startup.h>

extern struct Message *GetMsg();
extern int LoadSeg();
extern struct MsgPort *CreateProc();

struct P_Mess  {
   struct Message message;
   char *title;
   int files[3];
 };

extern int stdin;
extern int stdout;
extern int stderr;

struct MsgPort *NewProc,*Proc1,*Proc2;
int NewSeg,Seg1,Seg2;

main()
{
 struct Message *reply;
 struct Process *o_proc;

 struct WBStartup st1,st2;
 struct P_Mess pmes1,pmes2;
```

Listing 4-8. (cont.)

```
 struct MsgPort *o_rp;

 if(init_proc("p1_test","Process 1")==0)
   Exit();

 Seg1=NewSeg;
 Proc1=NewProc;

 if(init_proc("p1_test","Process 2")==0)
   Exit();

 Seg2=NewSeg;
 Proc2=NewProc;

 o_proc=(struct Process *)FindTask(0);
 o_rp=&o_proc->pr_MsgPort;

/**** startup first message ****/

 make_startup(&st1,o_rp);
 PutMsg(Proc1,&st1);

 make_message(&pmes1,"CON:10/10/320/150/New Process 1");

 PutMsg(Proc1,&pmes1);

/***** startup second process ****/

 make_startup(&st2,o_rp);

 PutMsg(Proc2,&st2);

 make_message(&pmes2,"CON:100/10/320/150/New Process 2");

 PutMsg(Proc2,&pmes2);

 WaitPort(o_rp);
 reply=GetMsg(o_rp);
 WaitPort(o_rp);
 reply=GetMsg(o_rp);
 UnLoadSeg(Seg1);

 WaitPort(o_rp);
 reply=GetMsg(o_rp);
 WaitPort(o_rp);
 reply=GetMsg(o_rp);
 UnLoadSeg(Seg2);

}

init_proc(fname,pname)
char *fname,*pname;
{
```

Listing 4-8. (cont.)

```
    if((NewSeg=LoadSeg(fname))==0)  {
       printf("Can't Create a Segment\n");
       return(0);
     }

    if((NewProc=CreateProc(pname,0,NewSeg,5000))==0)  {
       printf("Can't Create a Process\n");
       UnLoadSeg(NewSeg);
       return(0);
     }
    return(1);
}

make_startup(x,reply_port)
struct WBStartup *x;
struct MsgPort *reply_port;
{
     x->sm_Message.mn_ReplyPort=reply_port;
     x->sm_Message.mn_Length=sizeof(struct WBStartup);
     x->sm_Message.mn_Node.ln_Name="startup";
     x->sm_ArgList=NULL;
     x->sm_ToolWindow=NULL;
}
make_message(y,gist_of_it,reply_port)
struct P_Mess *y;
char *gist_of_it;
struct MsgPort *reply_port;
{
     y->message.mn_ReplyPort=reply_port;
     y->message.mn_Length=sizeof(struct P_Mes);
     y->message.mn_Node.ln_Name="p0_test";
     y->title=gist_of_it;
     y->files[0]=(int)stdin;
     y->files[1]=(int)stdout;
     y->files[2]=(int)stderr;
}
```

Summary

This has been a full chapter. We started out with a discussion of multiprocessing—running more than one program at a time. This led us to the notion of a process as opposed to a simple program. A process is program code that is executing in the machine or about to execute. Dealing with processes is a necessary step in creating multiprocessing environments, but it is not all that you need to know to implement these on the Amiga. It was necessary to take a digression into the message passing subsystem supplied by the executive kernel. We talked about ports and messages, and discussed how to create messages and pass them about within the machine.

Finally, we were able to talk about the details of implementing multiprocessing. There are two kinds available:

1. One process can spin off another and then wait for it to finish using the *Execute()* call in AmigaDOS.
2. You can produce wholly independent processes through a combination of the AmigaDOS system functions—*LoadSeg()*, *UnLoadSeg()*, and *CreateProc()*—and the Workbench start-up message.

Through a series of simple examples, we explored the techniques of these two methods.

Drawing in Intuition

Chapter 5

Intuition-Supported Graphics Functions
A Practical Gadget Library
ROM Kernel Graphics Commands
Some Miscellaneous Functions
A Simple Drawing Program
Summary

As you saw in Chapter 3, Intuition offers an interface system that is both intuitive to the user and simple to set up and use. In this chapter we will continue to explore the services offered by this window-oriented system. Here we will concentrate on the graphics facilities. Intuition makes it possible to create sophisticated displays with little more effort than it would take to set up a menu or gadget.

In the course of the chapter, we will return to some of the Intuition topics covered earlier. There, we used relatively simple examples, because you did not yet have the capabilities to create a fully visual object. Once you understand the many graphics functions, however, you will be able to create truly striking menus, gadgets, and requestors.

Finally, we will discuss the graphics functions found at the very core of the Amiga, in the ROM kernel. Intuition provides a convenient backdrop for exhibiting the full power of the graphics engine that is built into the Amiga hardware. You can do moves, draw lines and polygons, and do area fill at an amazing speed, because of the specialized graphics hardware. The specialized windows and screens that we briefly touched on in Chapter 3 will come into their own.

Intuition-Supported Graphics Functions

Intuition itself offers a useful selection of graphics functions. These are closely tied to its system of screens and windows, and support the auxiliary functions of menus, gadgets, and requestors. Although their main purpose is to manipulate the Intuition environment, these functions are by no means restricted to this secondary role. Frequently, the roles seem to be reversed, and a window may be opened so that a picture can be rendered by the drawing routines. At other times, it is the drawing that is subservient to a menu or a requester. No special preparation is required to use these functions. Since they are supported by Intuition, they can be used by opening Intuition itself as well as the graph-

ics library. Intuition takes care of any initialization necessary, and opens the appropriate libraries, making these functions even more attractive. As you will shortly see, much can be done with just these functions.

There are three kinds of graphics output associated with the Intuition graphics system.

1. Borders are lines or polygons drawn on the display area.
2. Images are pictures produced by altering the values of each pixel in the display area.
3. IntuiText is a character display rendered in a supplied or user-customized font.

The only apparent surprise in this list is the IntuiText object; however, a character display is really nothing more than a specialized picture. By treating it as straight graphics, Intuition offers a flexibility that is not available in many, otherwise powerful microcomputers. For example, text may be displayed in any font style you choose. This graphic treatment of text also facilitates the integration of traditional pictorial information in a document.

There is consistency among these basic graphics outputs. Each one shares a common form of construction and a common set of functions. There is a unique structure associated with each form—border, image, and IntuiText—yet there is a great similarity between these structures. The implementation of each form is also similar: *DrawBorder()*, *DrawImage()*, and *PrintIText()*. Each of these functions produces a display according to its appropriate form, yet each is similar to the other, having the same kind of setup specifications and parameters. In fact these functions are so alike that if you know how to create one of these objects, you can create the others. Of course, each of these data structures can be indirectly created through one of the other Intuition objects, such as a menu. Here there is a greater diversity of method, but still the underlying data structures are similar.

One final note before plunging into the definition and manipulation of Intuition graphics: with each of these objects, Intuition allows you to create a string of similar objects that can be dealt with in a single function call. You can create not only one Intuitext message, one set of lines or one single image with a function call, you can also create a whole screen full of these objects with that one call. This alone can greatly increase the effectiveness of graphic displays.

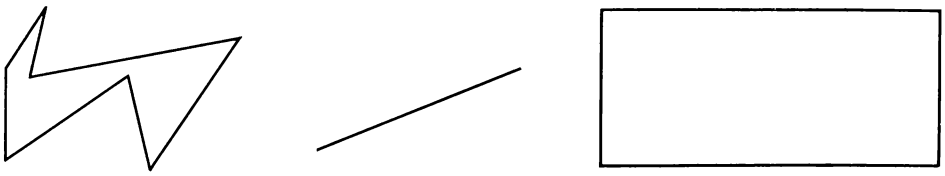
Setting a Border

Perhaps the most straightforward of these graphics objects is the border. The name is a historical accident; what you are really dealing with here is a generalized polygon drawing structure. A border can be:

- A single line
- An arbitrary collection of lines
- A true polygon

Of course, a border can be used to render the rectangular area around a window or screen. These basic configurations are illustrated in Figure 5-1.

Figure 5-1. Different kinds of borders



A border is defined by its corresponding structure.

```
struct Border  {
   SHORT LeftEdge,TopEdge,
         FrontPen,BackPen,
         DrawMode,
         Count,
         *XY;
   struct Border *NextBorder;
};
```

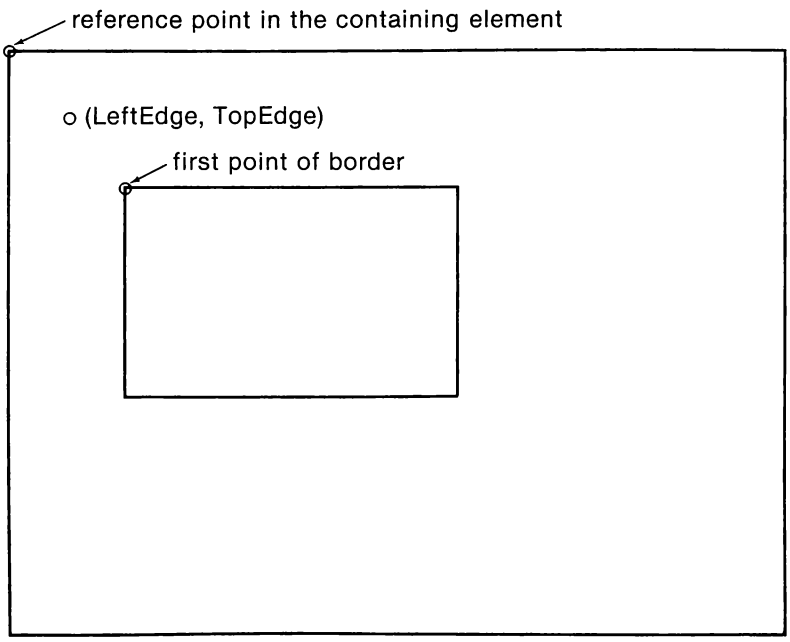
Each border structure is associated with an array of integers (the actual data type is SHORT), that define the end points of the lines that will make up this particular object.

LeftEdge and *TopEdge* define where the figure will appear within the enclosing structure. There is a natural tendency to see these two coordinates as the upper left-hand vertex of the proposed polygon. This may not be the case. *LeftEdge* and *TopEdge* actually define a reference point that sets the actual vertices of the figure: that is, those contained in the defining array. The point defined by these two values may, in fact, not even be a part of the drawn figure, and can even be enclosed by the figure it is used to measure. Figure 5-2 delineates the important relationships between this point and the rest of the drawing.

FrontPen is a pointer to a color register. It selects the color that will be used to draw the lines on the display. These colors must come from the current palette specified during the creation of the all-encompassing screen. This value will be further affected by the *DrawMode* field, which controls the way in which lines are painted on the display. Currently, the *BackPen* field is not used for drawing a border.

DrawMode selects one of two possible ways of drawing the lines that will trace out a desired figure. A value of JAM1 causes the display to trace between the various vertices, using the color specified in the *FrontPen* field. These lines are laid over the background color without changing it. In contrast, if this field is set with the COMPLEMENT flag, the border object will change the background to its binary complement along the figure lines.

Figure 5-2. The relationship of LeftEdge and TopEdge to the border figure



The field *XY* is a pointer to the array that contains the points that define the figure. The *Count* field indicates how many sides the figure has. It is important to note that the *Count* field is not the number of vertices, but is actually the number of pairs of coordinate points in the drawing. A mistake here or a change in this field can cause the same set of data to draw very different figures.

NextBorder is a pointer that allows a link to another border structure. Intuition enables such structures to form chains that will be given to the display, one after the other, by a single function call. This linked list of borders makes it possible to create efficient and complex displays. The last border structure in the chain must set this field to NULL.

Once defined and initialized, the border structure can be used in a variety of contexts to create a figure for display. You can use it in conjunction with one of the other Intuition objects—menus or gadgets, for example—to enhance the appearance and effectiveness of these constructions. You can also send it directly to the window or screen; this is done via the *DrawBorder()* function. This border output function has the general form:

```
DrawBorder(RPort,Border,L_Offset,T_Offset)
```

RPort is a pointer to the Raster Port address associated with the window or screen in which our drawing is to take place. *Border* is a pointer to the

defined and initialized border structure. *L_Offset* and *T_Offset* are values that will be added to the specified points in the vertex array. They allow a translation of the figure either up, down, or sideways in the display. These last two values can be zero.

Listing 5-1. The creation of a simple border structure in a window.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Window *NoBorder;
struct RastPort *r;

SHORT points[]={10,10,
                400,10,
                400,100,
                10,100,
                10,10};


struct Border lines={0,0,
                     5,0,
                     JAM1,
                     5,
                     NULL,
                     NULL};

main()
{
 ULONG flags;
 SHORT x,y,w,h;
 VOID delay_func(),OpenALL();

 OpenALL(); /* Carried over from Chapter 3 */

  /*  ======Open a borderless window======*/

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
  NoBorder=(struct Window *)make_window(x,y,w,h,NULL,flags);

 /*   ======Create a border structure========== */

  lines.XY=points;

  r=NoBorder->RPort;

  DrawBorder(r,&lines,0,0);


 /*   ======Delay for a bit to show off the windows====== */
```

Listing 5-1. (cont.)

```
  delay_func(100);

 /* =========Close down the windows in order========*/

  delay_func(10);


  CloseWindow(NoBorder);
}


VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Listing 5-1 shows a simple example of a directly rendered border. For the sake of simplicity, we pre-initialize an array of type SHORT to contain five pairs of coordinate values. Our border structure is also initialized to indicate the following characteristics for the figure:

FrontPen set to register 5

DrawingMode set to JAM1—a simple line output

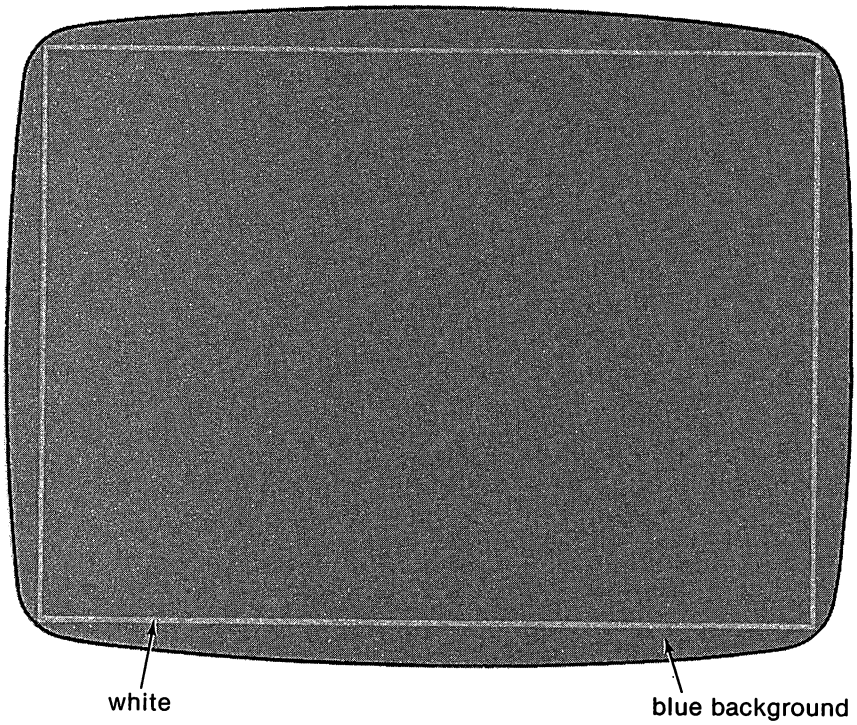
Count set to 5, to reflect the number of lines that make up the figure

As with all the examples in this chapter, we use the support library we defined in Chapter 3.

Figure 5-3 shows the output from this example program. Listing 5-2 shows a somewhat more ambitious undertaking. This program contains a set of linked border structures. These structures create a more complex figure, but with only a single call to the function *DrawBorder()*. Notice how the *FrontPen* field of each border object has been assigned a different color to produce a more striking display. Note, too, that the *NextBorder* field of the last structure in the chain has been set to NULL. Figure 5-4 displays the output of this program.

The border structure can actually serve as a model for the other two objects. As you will see, Intuition is remarkably consistent in these operations. This situation makes life much easier for the programmer who wants to create very complex user interfaces and displays.

Figure 5-3. The output of Listing 5-1



Listing 5-2. The creation of several linked border structures in a window.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Window *NoBorder;
struct RastPort *r;

SHORT points[][10]={{0,0,600,0,600,150,0,150,0,0},
                    {10,10,590,10,590,140,10,140,10,10},
                    {20,20,580,20,580,130,20,130,20,20},
                    {30,30,570,30,570,120,30,120,30,30}};

struct Border lines[4];

main()
{
 ULONG flags;
 SHORT x,y,w,h;
 VOID delay_func(),OpenALL();

 OpenALL();
```

Listing 5-2. (cont.)

```
 /*  ======Open a borderless window======*/

 x=y=0;
 w=640;
 h=200;
 flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
 NoBorder=(struct Window *)make_window(x,y,w,h,NULL,flags);

/*   ======Create a border structure========== */

 lines[0].LeftEdge=0;
 lines[0].TopEdge=0;
 lines[0].FrontPen=1;
 lines[0].BackPen=0;
 lines[0].DrawMode=JAM1;
 lines[0].Count=5;
 lines[0].XY=&points[0][0];
 lines[0].NextBorder=&lines[1];

 lines[1].LeftEdge=0;
 lines[1].TopEdge=0;
 lines[1].FrontPen=2;
 lines[1].BackPen=0;
 lines[1].DrawMode=JAM1;
 lines[1].Count=5;
 lines[1].XY=&points[1][0];
 lines[1].NextBorder=&lines[2];

 lines[2].LeftEdge=0;
 lines[2].TopEdge=0;
 lines[2].FrontPen=3;
 lines[2].BackPen=0;
 lines[2].DrawMode=JAM1;
 lines[2].Count=5;
 lines[2].XY=&points[2][0];
 lines[2].NextBorder=&lines[3];

 lines[3].LeftEdge=0;
 lines[3].TopEdge=0;
 lines[3].FrontPen=4;
 lines[3].BackPen=0;
 lines[3].DrawMode=JAM1;
 lines[3].Count=5;
 lines[3].XY=&points[3][0];
 lines[3].NextBorder=NULL;

 r=NoBorder->RPort;

 DrawBorder(r,&lines[0],10,10);


/*   ======Delay for a bit to show off the windows====== */
```

Listing 5-2. (cont.)

```
  delay_func(100);

 /* =========Close down the windows in order========*/

  delay_func(10);


  CloseWindow(NoBorder);
}


VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

IntuiText

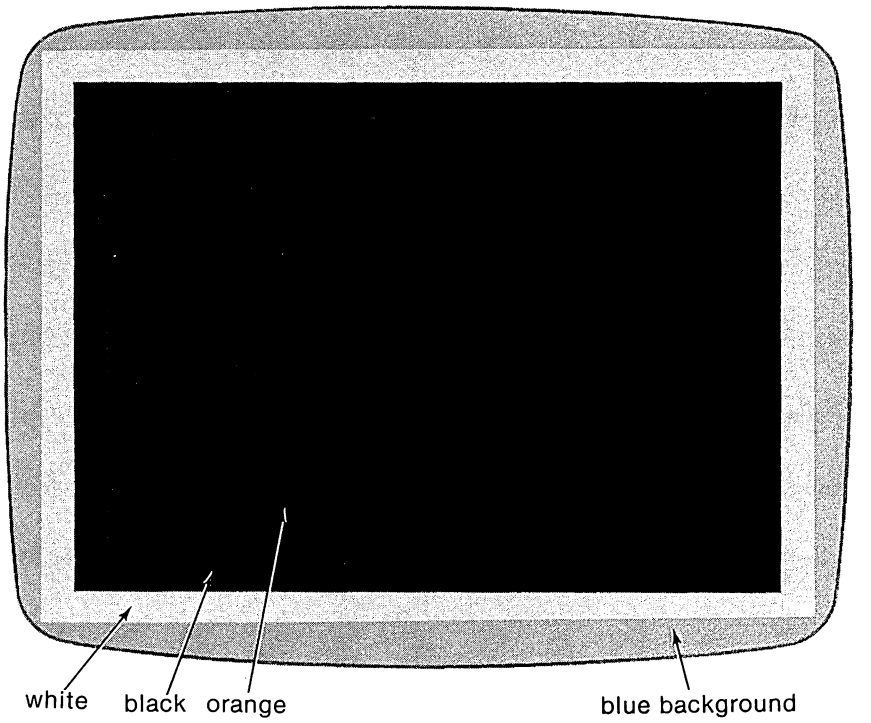
Although Intuition offers specialized functions and support routines, along with data structures for putting text onto the display screen text, it is still just another type of graphics object. Remembering this will help you to keep straight the steps needed for this kind of display. Like the border, text has its own structure—*IntuiText*. It is necessary to create and initialize this structure before you can render text. The IntuiText structure has the form:

```
struct IntuiText  {
   UBYTE FrontPen,BackPen,
         DrawMode
   SHORT LeftEdge,TopEdge;
   struct TextAttr *ITextFont;
   UBYTE *IText;
   struct IntuiText *NextText;
};
```

As with the border structure, there are associated data structures peculiar to the IntuiText structure, as well as some that are common to all of Intuition's graphics objects.

ITextFont points to a structure that defines a particular type font. If you set this parameter to NULL, the text is rendered in the default style for that window or screen. Several fonts are available in the Font Library, and the Amiga allows the creation of new ones. *IText* is another pointer, this time to a

Figure 5-4. Output of Listing 5-2



character string—an array of characters terminated by the '\0' character. This string contains the actual characters that make up this IntuiText structure.

LeftEdge and *TopEdge* perform the same function here as they do with the border. These two values form a reference coordinate from which the text position will be measured.

FrontPen and *BackPen* each contain the value of a color register. *DrawMode* sets the way in which text will be presented. The rendering of text on a display is somewhat more intricate than with the simpler border structure. As a result, the relationship between *DrawMode*, *FrontPen* and *BackPen* is correspondingly more complex. The simplest case is set by choosing JAM1 as the *DrawMode*. The text is rendered in the chosen font, in the color set by *FrontPen*, on the background of the display window or screen. A mode of JAM2 causes the characters to be displayed in the color indicated by *FrontPen*, but the background underneath will be changed by the *BackPen* reference. COMPLEMENT mode draws the characters, by tracing their outlines in the binary complement of the background color.

Finally, *NextText* allows you to set up a string of IntuiText structures. You can produce several lines of output with a single function call.

The system call that translates your initialized structure to a display is:

```
PrintIText(RPort,IText,L_Offset,T_Offset)
```

Where *RPort* is a pointer to the enclosing objects RastPort, *IText* is a pointer to the IntuiText structure, and *L_Offset* and *T_Offset* are translation values. These last two are added to the position values created by the structure itself. They allow you to reposition the text anywhere in the display without altering the structure. This translation capability is particularly handy if you are displaying the same text in a number of different objects within the display. You can have independent control of the text location in each object. You can also change text positions in one object without affecting the display elsewhere.

A useful function unique to the IntuiText structure is:

```
IntuiTextLength(IText);
```

IText is a pointer to an IntuiText structure. This function returns the length of the display in pixels. This function is necessary whenever you need to know how much space a text display will require. Since text can be rendered in different fonts, the actual size of a given line of text can vary over a wide range. In any case, the pixel is a more appropriate unit of measure than the character.

Listing 5-3 shows an example of a simple IntuiText structure in a window. We create the structure, initialize it, and use it as a parameter in a call to *PrintIText()*. We use the simplest situation and draw the text using the color pointed to by *FrontPen*. Note that we use an offset value of 0,0 in the function call. In this particular case, *r* is a pointer to the window's RastPort. Figure 5-5 shows the resulting display.

Listing 5-3. The creation of a simple IntuiText structure in a window.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Window *NoBorder;
struct RastPort *r;

struct IntuiText mesg;

main()
{
 ULONG flags;
 SHORT x,y,w,h;
 VOID delay_func(),OpenALL();

 OpenALL(); /* Add error checking */

  /*  ======Open a borderless window======*/

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
  NoBorder=(struct Window *)make_window(x,y,w,h,NULL,flags);
```

Listing 5-3. (cont.)

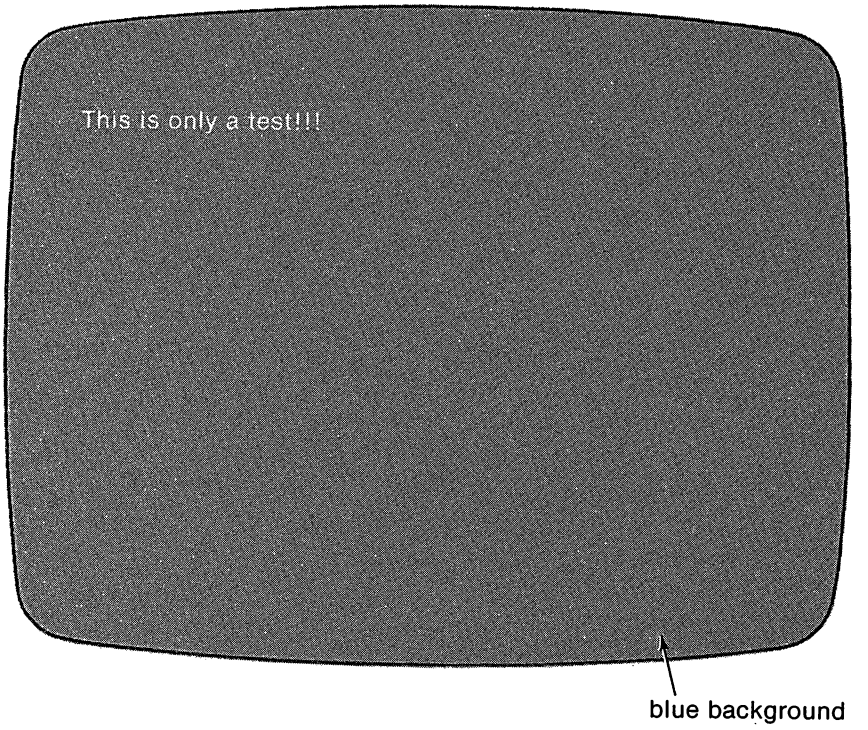
```
 /*   ======Create an IntuiText structure========== */

  mesg.FrontPen=5;
  mesg.BackPen=1;
  mesg.DrawMode=JAM1;
  mesg.LeftEdge=10;
  mesg.TopEdge=10;
  mesg.ITextFont=NULL;
  mesg.IText=(UBYTE *)"This is only a Test!!!";
  mesg.NextText=NULL;
  r=NoBorder->RPort;

  PrintIText(r,&mesg,0,0);


 /*   ======Delay for a bit to show off the windows====== */

  delay_func(100);

 /* =========Close down the windows in order========*/

  delay_func(10);


  CloseWindow(NoBorder);
}


VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Listing 5-4 is a more ambitious program. Here we display several linked IntuiText structures. Again, we use the simple JAM1 *DrawMode*. The result of this program is shown in Figure 5-6.

Listing 5-4. Creation of linked IntuiText structures in a window.

```
#include <exec/types.h>
#include <intuition/intuition.h>
```

Figure 5-5. Output of Listing 5-3



Listing 5-4. (cont.)

```
struct Window *NoBorder;
struct RastPort *r;

struct IntuiText mesg[3];

main()
{
 ULONG flags;
 SHORT x,y,w,h;
 VOID delay_func(),OpenALL();

 OpenALL();

  /*  ======Open a borderless window======*/

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
  NoBorder=(struct Window *)make_window(x,y,w,h,NULL,flags);
```

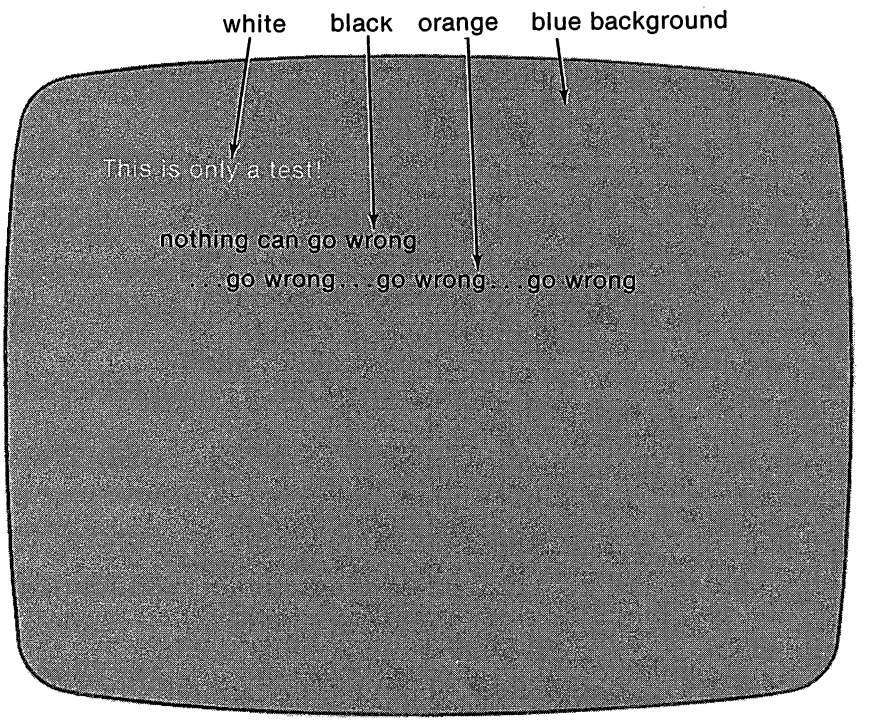
Listing 5-4. (cont.)

```
 /*   ======Create an IntuiText structure========== */

  mesg[0].FrontPen=5;
  mesg[0].BackPen=1;
  mesg[0].DrawMode=JAM1;
  mesg[0].LeftEdge=0;
  mesg[0].TopEdge=0;
  mesg[0].ITextFont=NULL;
  mesg[0].IText=(UBYTE *)"This is only a Test.";
  mesg[0].NextText=&mesg[1];

  mesg[1].FrontPen=6;
  mesg[1].BackPen=1;
  mesg[1].DrawMode=JAM1;
  mesg[1].LeftEdge=30;
  mesg[1].TopEdge=10;
  mesg[1].ITextFont=NULL;
  mesg[1].IText=(UBYTE *)"Nothing can go wrong...";
  mesg[1].NextText=&mesg[2];

  mesg[2].FrontPen=7;
  mesg[2].BackPen=1;
  mesg[2].DrawMode=JAM1;
  mesg[2].LeftEdge=60;
  mesg[2].TopEdge=20;
  mesg[2].ITextFont=NULL;
  mesg[2].IText=(UBYTE *)"...go wrong...go wrong...";
  mesg[2].NextText=NULL;

  r=NoBorder->RPort;

  PrintIText(r,&mesg,0,20);


 /*   ======Delay for a bit to show off the windows====== */

  delay_func(100);

 /* =========Close down the windows in order========*/

  delay_func(10);


  CloseWindow(NoBorder);
}


VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
```

Listing 5-4. (cont.)

```
    ;

  return;
}
```

Figure 5-6. Output of Listing 5-4



In this section, we have been concerned with creating and directly displaying text in a window or screen. But text can also be part of menus, gadgets, alerts, and requesters. The procedures are different in these more complicated cases, but they still utilize the IntuiText structure to define that part of the display. Some examples of these topics in Chapter 3 used this kind of structure without fully explaining it. We will turn our attention back to these objects and their relationship to text display later in this chapter.

Images

The most primitive of all Intuition graphics objects is the *image*. The image creates a display by specifying the color information contained in each pixel of

a proposed figure. Rather than creating a picture with a series of lines, you interact at the level of the display itself, indicating which areas will be light and dark, and putting a specific color at a specific location. Intuition still shields you from the many details necessary to produce such a display. It gives you the capability of creating an image and displaying it anywhere on the display surface . . . even rendering the same image in more than one object.

As with a border, an image is defined in two parts. The image structure carries the information needed to find a place for the object and to render it successfully. Contained in the image structure is a pointer to the actual pixel-by-pixel information that specifies the shape and the colors of the displayed image. This information is contained in an array, but the situation is more complex than with the straightforward border array.

The image-defining structure is deceptively short:

```
struct Image  {
   SHORT LeftEdge, TopEdge,
         Width, Height, Depth,
         *ImageData;
   UBYTE PlanePick, PlaneOnOff;
   struct Image *NextImage;
};
```

This structure maintains the same consistent design found in the two earlier structures: the positioning information and the pointer to the next graphic object. But there are some significant differences.

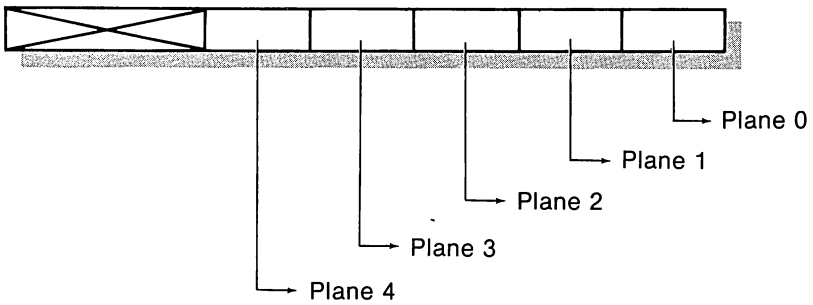
Once you have created an object, *LeftEdge* and *TopEdge* allow you to move it around and position it anywhere within the visible display area. These two values represent a reference coordinate from which the painting of the image can be done. This is similar to the situation with border or even IntuiText objects. The *width* and *height* fields, in contrast, have a more active role to play in the creation of an object. These two values indicate roughly the size of the object; they define a rectangular region within which your design is created.

NextImage is a pointer to another image structure. With this, you can maintain the Intuition tradition of specifying a chain of images that can be controlled by a single function call. This adds to the efficiency and elegance of graphics under Intuition. It also cancels out any overhead that might have been incurred by using this high-level interface to the system. *ImageData* is another pointer; this one refers to an array that contains a series of 16-bit words. These words are logically manipulated into a rectangular display area (a bit map) which, in turn, is translated by the hardware into an image on the display screen. The height and width fields are used to make this translation. Each bit in each word is associated with a different pixel on the screen. By manipulating the value of the bit, you can alter the display of the corresponding pixel.

A single rectangular area allows you to produce a monochrome display. Either the pixel is on or off. The *Depth* field allows you to specify more than one of these bit planes. With more bit planes, you open up the possibility of multiple colors in the display. The image structure allows extra flexibility with the *PlanePick* and *PlaneOnOff* fields. By manipulating these fields, you

can easily change the display characteristics of an image object. The *PlanePick* field allows you to match the bit planes of the image structure with the bit planes of the enclosing window or screen (Figure 5-7). *PlaneOnOff* lets Intuition know what to do with the bit planes that are not matched to the image. *Depth* specifies directly the number of bit planes used in the picture and thus, indirectly, the colors available to your pixels.

Figure 5-7. The bit mask relationships for PlanePick



The final stage in the process is a call to the Intuition function:

```
DrawImage(RPort,ImagePtr,Xoffset,Yoffset);
```

RPort points to the RastPort structure for the window or screen that displays the image. *ImagePtr* points to the current image structure. *Xoffset* and *Yoffset* provide displacement values for the object's position on the display surface.

Listing 5-5. Creation of a simple image structure in a window.

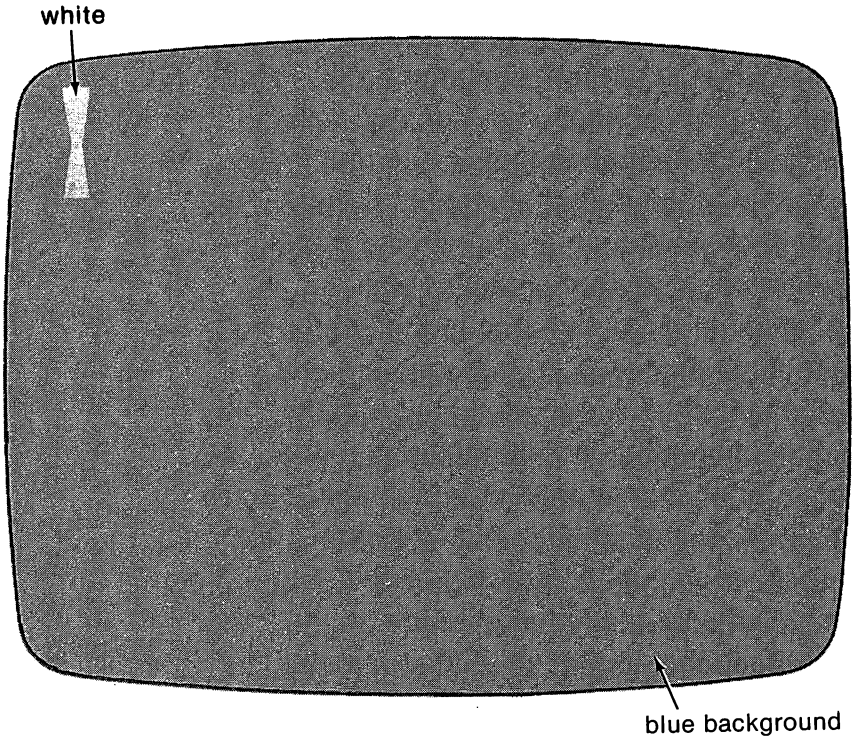
```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Window *NoBorder;
struct RastPort *r;

USHORT imagepts[]={0xffff,0x4ffe,0x3ffc,0x1ff8,
                   0x0ff0,0x07e0,0x03c0,0x03c0,
                   0x03c0,0x03c0,0x07f0,0x0ff0,
                   0x1ff8,0x3ffc,0x4ffe,0xffff};

struct Image picture={0,0,
                      16,16,
                      3,
                      NULL,
                      0x0001,0x0000,
                      NULL};

main()
```

Listing 5-5. (cont.)

```
{
 ULONG flags;
 SHORT x,y,w,h;
 VOID delay_func(),OpenALL();

 OpenALL();

  /*  ======Open a borderless window======*/

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
  NoBorder=(struct Window *)make_window(x,y,w,h,NULL,flags);

 /*   ======Create an image structure========== */

  picture.ImageData=imagepts;

  r=NoBorder->RPort;

  DrawImage(r,&picture,0,0);


 /*   ======Delay for a bit to show off the windows====== */

  delay_func(100);

 /* =========Close down the windows in order========*/

  delay_func(10);


  CloseWindow(NoBorder);
}


VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Listing 5-5 illustrates some of these points. We initialize an array, *imagepts[]*, with the values that will render our image. Also initialized is an image structure. The offset is 0, the size of the image is 16 by 16, and all other

Figure 5-8. Output of Listing 5-5



fields are set to the defaults for the enclosing display object. A call to *DrawImage()* finishes the action. The result is shown in Figure 5-8. Note that the offset in both the image structure and in the function call is 0,0.

As with the previous two graphics objects, it is possible to create a string of images with a single call to *DrawImage()*. The image structures are connected in a linked list and the first one on this list is sent to the function as a parameter. Note that the offset values that are also sent as parameters will be applied to each image, not just to the first one. It is best to use the *LeftEdge* and *TopEdge* fields in the individual structures in this situation. Listing 5-6 shows this procedure in action. Here we create an array of image structures, link them together, and finally call *DrawImage()*. Notice how we use the same set of points for each structure. As with our earlier example, we use *LeftEdge* and *TopEdge* to set the displacement for each object.

Listing 5-6. The creation of several image structures in a window.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Window *NoBorder;
struct RastPort *r;
```

Listing 5-6. (cont.)

```
USHORT imagepts[]={0xffff,0x4ffe,0x3ffc,0x1ff8,
                   0x0ff0,0x07e0,0x03c0,0x03c0,
                   0x03c0,0x03c0,0x07f0,0x0ff0,
                   0x1ff8,0x3ffc,0x4ffe,0xffff};


struct Image picture[3];

main()
{
 ULONG flags;
 SHORT x,y,w,h;
 VOID delay_func(),OpenALL();

 OpenALL();

  /*  ======Open a borderless window======*/

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
  NoBorder=(struct Window *)make_window(x,y,w,h,NULL,flags);

 /*   ======Create image structures========== */

  picture[0].LeftEdge=0;
  picture[0].TopEdge=0;
  picture[0].Width=16;
  picture[0].Height=16;
  picture[0].Depth=1;
  picture[0].ImageData=imagepts;
  picture[0].PlanePick=0x0001;
  picture[0].PlaneOnOff=0x0000;
  picture[0].NextImage=&picture[1];

  picture[1].LeftEdge=50;
  picture[1].TopEdge=10;
  picture[1].Width=16;
  picture[1].Height=16;
  picture[1].Depth=1;
  picture[1].ImageData=imagepts;
  picture[1].PlanePick=0x0001;
  picture[1].PlaneOnOff=0x0000;
  picture[1].NextImage=&picture[2];

  picture[2].LeftEdge=100;
  picture[2].TopEdge=20;
  picture[2].Width=16;
  picture[2].Height=16;
  picture[2].Depth=1;
  picture[2].ImageData=imagepts;
  picture[2].PlanePick=0x0001;
```

Listing 5-6. (cont.)

```
  picture[2].PlaneOnOff=0x0000;
  picture[2].NextImage=NULL;

  r=NoBorder->RPort;

  DrawImage(r,&picture,300,50);


 /*   ======Delay for a bit to show off the windows====== */

  delay_func(100);

 /* =========Close down the windows in order========*/

  delay_func(10);


  CloseWindow(NoBorder);
}


VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Using Graphics with Gadgets

User-defined gadgets without some striking display on the screen are not particularly effective; those that do draw pictures are extremely so. System-defined gadgets clearly illustrate this point. In Chapter 3, we talked at length about these devices and how to set them up, but our examples were universally disappointing. Here, we will remedy that defect with a series of graphics-oriented examples.

Listing 5-7. Window with a string gadget rendered with a complex double border.

```
#include <exec/types.h>
#include <intuition/intuition.h>
```

Listing 5-7. (cont.)

```
struct Screen *Scrn;
struct Window *wind0,*wind1;
struct Gadget gadget;
struct StringInfo info;

SHORT brd0[]={0,0,200,0,200,12,0,12,0,0},
      brd1[]={0,0,210,0,210,16,0,16,0,0};

struct Border border0={-2,-2,1,0,JAM1,5,brd0,NULL},
              border1={-7,-4,2,0,JAM1,5,brd1,NULL};


main()
{
 ULONG flags;
 SHORT x,y,w,h,d;
 USHORT mode;
 UBYTE *name,c0,c1;
 VOID delay_func(),OpenALL();
 char dobuffer[80],undobuffer[80];

  OpenALL();
 /*  ======First create a gadget========= */

  strcpy(dobuffer,"Enter New Text Here");
  border0.NextBorder=&border1;

  info.Buffer=dobuffer;
  info.UndoBuffer=undobuffer;
  info.MaxChars=80;
  info.BufferPos=0;
  info.DispPos=0;

  gadget.NextGadget=NULL;
  gadget.LeftEdge=40;
  gadget.TopEdge=40;
  gadget.Width=199;
  gadget.Height=15;
  gadget.Flags=GADGHBOX;
  gadget.Activation=TOGGLESELECT;
  gadget.GadgetType=STRGADGET;
  gadget.GadgetRender=(APTR)&border0;
  gadget.SelectRender=NULL;
  gadget.GadgetText=NULL;
  gadget.MutualExclude=NULL;
  gadget.SpecialInfo=(APTR)&info;
  gadget.GadgetID=NULL;
  gadget.UserData=NULL;

 /*  ======Open a hi-res custom screen==== */

  name="The Gadget Screen";
  y=0;
  w=640;
```

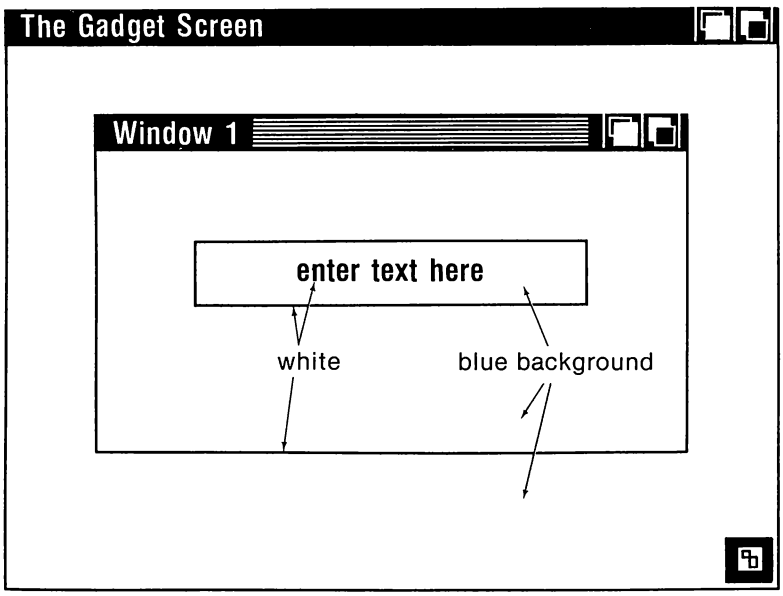
Listing 5-7. (cont.)

```
  h=200;
  d=3;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,name);

 /*  =======Open a window==============*/

  name="Window 1";
  x=20;
  y=20;
  w=400;
  h=150;
  flags=ACTIVATE|WINDOWSIZING|WINDOWDEPTH|WINDOWDRAG|
                              WINDOWCLOSE|SMART_REFRESH;
  c0=-0x01;
  c1=-0x01;

  wind0=(struct Window *)
           make_window(x,y,w,h,name,flags,c0,c1,Scrn,&gadget);

 /*   ======Delay for a bit to show off the window====== */

  delay_func(100);

 /* =========Close down the window then the screen========*/

  CloseWindow(wind0);

  CloseScreen(Scrn);

}

VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Listing 5-7 shows a string gadget rendered with a double border around its select box. The result is shown in Figure 5-9. To accomplish this display, we first create two border structures: *border0* and *border1*. There is some-

thing new with this definition; we specify *LeftEdge* and *TopEdge* as negative quantities. The enclosing object in this case is the select box of the gadget. By using a negative offset, we can position our border figure outside of this select box, even though our reference is this figure. *Border0* and *border1* are connected together into a linked list, but instead of a call to the *DrawBorder()* function, we set the *GadgetRender* field to the address of *border0*. When the gadget is summoned, the figure will be automatically drawn. The same techniques can be used with an integer or a boolean gadget.

Figure 5-9. Output of Listing 5-7



In Listing 5-8, we have a more complex kind of gadget, the proportional gadget. As you saw in Chapter 3, this simulates the kind of control found with an analog device in the real world—such as a control knob. Without a graphics interface, it is impossible to create an effective gadget of this type.

Listing 5-8. A window with a proportional gadget.

```
#include <exec/types.h>
#include intuition/intuition.h>

struct Screen *Scrn;
struct Window *wind0,*wind1;
struct Gadget gadget;
struct PropInfo info;
struct Image image;
struct IntuiText message={1,0,
                          JAM1,
                          -2,-9,
```

Listing 5-8. (cont.)

```
                        NULL,
                        "This is only a test!",
                        NULL};


#define INTUITION_REV 29


main()
{
 ULONG flags;
 SHORT x,y,w,h,d;
 USHORT mode;
 UBYTE *name,c0,c1;
 VOID delay_func(),OpenALL();

  OpenALL();

 /*  ======First create a gadget========= */

  info.Flags=AUTOKNOB|FREEHORIZ|KNOBHIT;
  info.HorizPot=0;
  info.VertPot=0;
  info.HorizBody=0x0001;
  info.VertBody=0x0001;

  gadget.NextGadget=NULL;
  gadget.LeftEdge=40;
  gadget.TopEdge=40;
  gadget.Width=199;
  gadget.Height=10;
  gadget.Flags=GADGHCOMP;
  gadget.Activation=NULL;
  gadget.GadgetType=PROPGADGET;
  gadget.GadgetRender=(APTR)&image;
  gadget.SelectRender=NULL;
  gadget.GadgetText=&message;
  gadget.MutualExclude=NULL;
  gadget.SpecialInfo=(APTR)&info;
  gadget.GadgetID=NULL;
  gadget.UserData=NULL;

 /*  ======Open a hi-res custom screen==== */

  name="The Gadget Screen";
  y=0;
  w=640;
  h=200;
  d=3;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
```

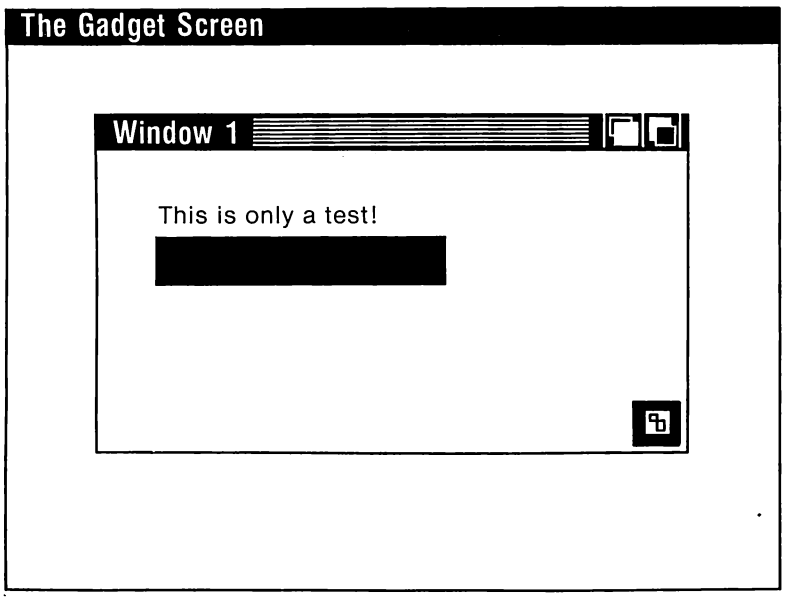
Listing 5-8. (cont.)

```
          make_screen(y,w,h,d,c0,c1,mode,name);

 /*  =======Open a window==============*/

  name="Window 1";
  x=20;
  y=20;
  w=400;
  h=150;
  flags=ACTIVATE|WINDOWSIZING|WINDOWDEPTH|WINDOWDRAG|
                              WINDOWCLOSE|SMART_REFRESH;
  c0=-0x01;
  c1=-0x01;

  wind0=(struct Window *)
          make_window(x,y,w,h,name,flags,c0,c1,Scrn,&gadget);

 /*   ======Delay for a bit to show off the window====== */

  delay_func(100);

 /* =========Close down the window then the screen========*/

  CloseWindow(wind0);

  CloseScreen(Scrn);

}

VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Recall that a proportional gadget requires a Special Info structure in addition to the gadget structure itself. This Info structure defines the values of the control interface portion of the gadget. Besides initializing the values of the control fields, in this structure you must also set certain key values that affect the display of the gadget. These values are set in the *Flags* field of this structure and include:

FREEHORIZ or FREEVERT to indicate the direction of movement of the control device

Figure 5-10. Output of Listing 5-8



PROPBORDERLESS to display the gadget without a border around the container of the control device

AUTOKNOB to indicate the default control device shape

It is possible to create your own control object, but AUTOKNOB is a convenient default that produces an effective display. It shows the control surface as a rectangle within an outer rectangle that serves as a containing surface. In Listing 5-8, we have a control device that moves in the horizontal direction. There are two further things to note about the example in Listing 5-8. Even though we are using the default AUTOKNOB object, we must declare an image structure and assign its address to the *GadgetRender* field of the gadget structure. This area is used by Intuition to build the AUTOKNOB object. This example also uses an IntuiText structure to place text into the gadget display. The gadget's *GadgetText* field is set to the address of this structure. This gadget is displayed in Figure 5-10.

In Listing 5-9, we take our proportional gadget a step further. Here we define two complementary gadgets: one moves horizontally; the other, vertically. Notice that the two gadgets are also elegantly connected in a linked list. The result is visible in Figure 5-11.

Listing 5-9. A window with two proportional gadgets.

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Screen *Scrn;
```

Listing 5-9. (cont.)

```
struct Window *wind0,*wind1;
struct Gadget gadget0,gadget1;
struct PropInfo info0,info1;
struct Image image0,image1;
struct IntuiText message={1,0,
                          JAM1,
                          -2,-9,
                          NULL,
                          "This is only a test!",
                          NULL};


main()
{
 ULONG flags;
 SHORT x,y,w,h,d;
 USHORT mode;
 UBYTE *name,c0,c1;
 VOID delay_func(),OpenALL();

  OpenALL();

 /*  ======First create a gadget========= */

  info0.Flags=AUTOKNOB|FREEHORIZ|KNOBHIT;
  info0.HorizPot=0;
  info0.VertPot=0;
  info0.HorizBody=0x0001;
  info0.VertBody=0x0001;

  gadget0.NextGadget=(APTR)&gadget1;
  gadget0.LeftEdge=40;
  gadget0.TopEdge=40;
  gadget0.Width=199;
  gadget0.Height=10;
  gadget0.Flags=GADGHCOMP;
  gadget0.Activation=NULL;
  gadget0.GadgetType=PROPGADGET;
  gadget0.GadgetRender=(APTR)&image0;
  gadget0.SelectRender=NULL;
  gadget0.GadgetText=&message;
  gadget0.MutualExclude=NULL;
  gadget0.SpecialInfo=(APTR)&info0;
  gadget0.GadgetID=NULL;
  gadget0.UserData=NULL;

  info1.Flags=AUTOKNOB|FREEVERT|KNOBHIT;
  info1.HorizPot=0;
  info1.VertPot=0;
  info1.HorizBody=0x0001;
  info1.VertBody=0x0001;

  gadget1.NextGadget=NULL;
  gadget1.LeftEdge=40;
```

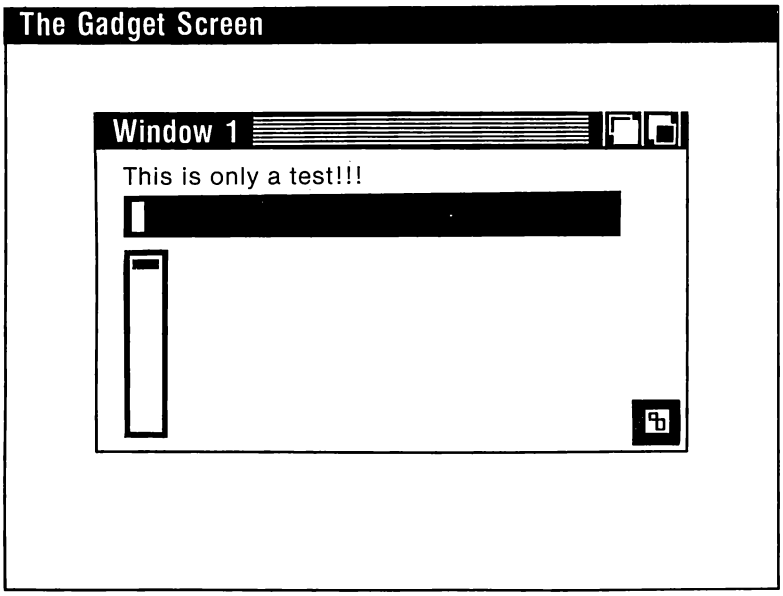
Listing 5-9. (cont.)

```
  gadget1.TopEdge=55;
  gadget1.Width=20;
  gadget1.Height=75;
  gadget1.Flags=GADGHCOMP;
  gadget1.Activation=NULL;
  gadget1.GadgetType=PROPGADGET;
  gadget1.GadgetRender=(APTR)&image1;
  gadget1.SelectRender=NULL;
  gadget1.GadgetText=NULL;
  gadget1.MutualExclude=NULL;
  gadget1.SpecialInfo=(APTR)&info1;
  gadget1.GadgetID=NULL;
  gadget1.UserData=NULL;
 /*  ======Open a hi-res custom screen==== */

  name="The Gadget Screen";
  y=0;
  w=640;
  h=200;
  d=3;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,name);

 /*  =======Open a window==============*/

  name="Window 1";
  x=20;
  y=20;
  w=400;
  h=150;
  flags=ACTIVATE|WINDOWSIZING|WINDOWDEPTH|WINDOWDRAG|
                              WINDOWCLOSE|SMART_REFRESH;
  c0=-0x01;
  c1=-0x01;

  wind0=(struct Window *)
           make_window(x,y,w,h,name,flags,c0,c1,Scrn,&gadget0);

 /*   ======Delay for a bit to show off the window====== */

  delay_func(100);

 /* =========Close down the window then the screen========*/

  CloseWindow(wind0);

  CloseScreen(Scrn);

}
```

Listing 5-9. (cont.)

```
VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

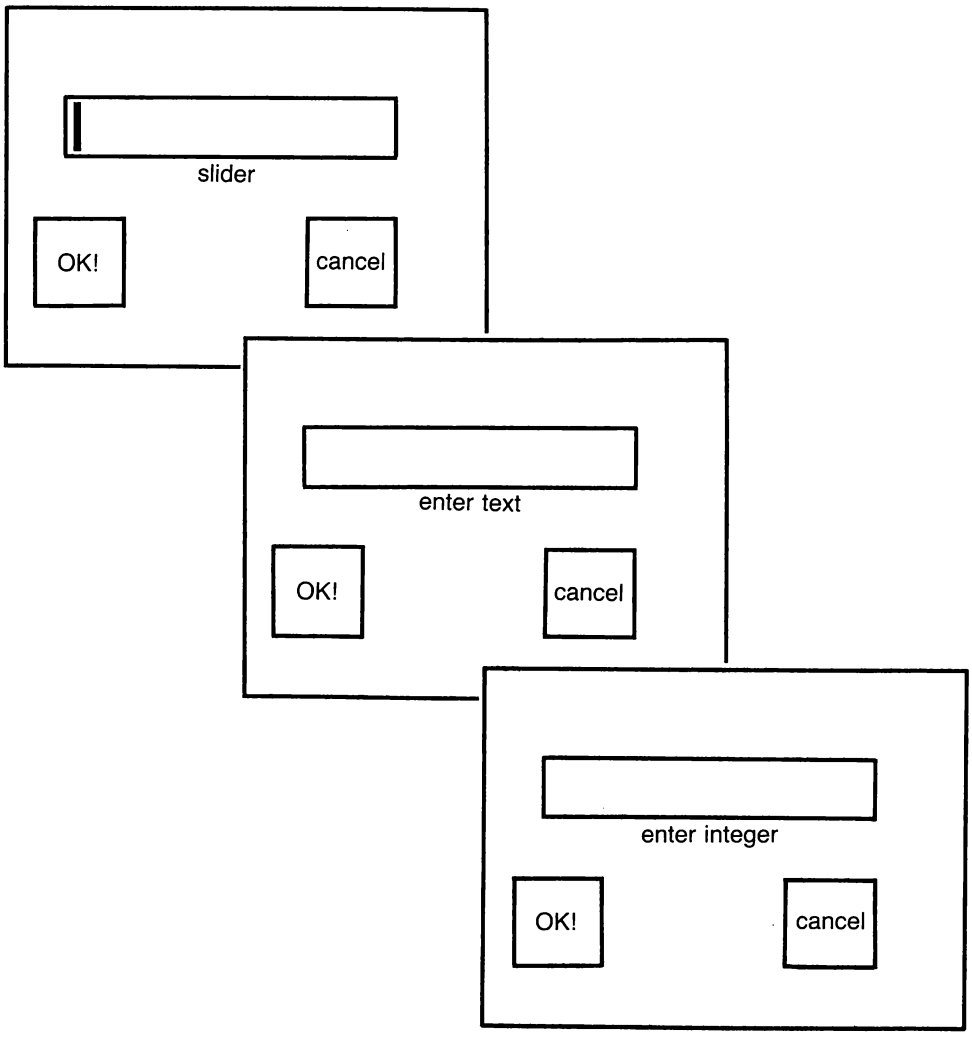
Figure 5-11. Output of Listing 5-9



A Practical Gadget Library

Gadgets are such an integral part of the Intuition operating environment that it would certainly be useful to call up such an object whenever the need arose. Just as the C programmer can call upon getchar( ) or scanf( ) to grab values from stdin without any special attention to the details of these functions, an Intuition programmer could use comparable gadget functions that return requested values. Figure 5-12 illustrates three such gadgets: one for proportional input, one for string input, and one with an integer gadget.

Figure 5-12 A package of three gadgets



Some attention should be paid to the graphic design of these library gadgets. Note first that they are all similar in labelling and layout. Note further that each gadget is a window containing a composite gadget. Two Boolean ones, titled OK! and Cancel, actually control the operation of the composite object. Values are placed in the main gadget, whether string or proportional or integer, but nothing is returned until one of the Boolean ones is clicked. They perform a function similar to the carriage return with the *getchr()* or scanf( ) functions in C.

Listing 5-10 contains the code for the library functions. First, the data structures defining the gadgets must be declared and defined. Each of the five gadgets has its own definition although some of the data structures

could be shared. Since these are to be standard gadgets, we can initialize the structures in the declaration step rather than making an explicit assignment in each field. The function *get_flag()* handles the i/o from the two Boolean gadgets. It returns a value of 1, if the OK! was clicked. A selection of the Cancel gadget will yield a zero. Input is taken through the IDCMP subsystem associated with the enclosing window. Once a GADGETUP event is sensed, the IAddress field of the IntuiMessage structure is queried for the gadget address: ogadget or cgadget. The flag is set accordingly and a return is made from the function. No return is possible until a choice is made.

Listing 5-10. A library of gadget access routines.

```
#include <exec/types.h>
#include <intuition/intuition.h>

/* define the proportional gadget */

struct PropInfo pgadg={AUTOKNOB|FREEHORIZ,0,0,0X0000,0X0000,0,0,0,0,0};
struct Image pimage;
struct IntuiText pprompt = {3,0,JAM2,108,30,NULL,"SLIDER",NULL};
struct Gadget pgadget={NULL,45,37,267,25,GADGHCOMP,RELVERIFY,PROPGADGET,
                       (APTR)&pimage,NULL,&pprompt,0,(APTR)&pgadg,
                       2,NULL};

/* define the string gadget */

struct StringInfo sgadg = {NULL,NULL,0,80,0,0,0,0,0,0,0,NULL,NULL};
USHORT spts[] = {0,0,310,0,310,13,0,13,0,0};
struct Border sborder={-2,-3,3,0,JAM1,5,spts,NULL};
struct IntuiText sprompt={3,0,JAM2,111,15,NULL,"Enter text",NULL};
struct Gadget sgadget={NULL,28,29,307,10,GADGHCOMP,RELVERIFY,
                       STRGADGET,(APTR)&sborder,NULL,&sprompt,0,
                       (APTR)&sgadg,1,NULL};

/* define the integer gadget */

struct StringInfo igadg = {NULL,NULL,0,80,0,0,0,0,0,0,0,NULL,NULL};
USHORT ipts[] = {0,0,310,0,310,13,0,13,0,0};
struct Border iborder={-2,-3,3,0,JAM1,5,ipts,NULL};
struct IntuiText iprompt={3,0,JAM2,111,15,NULL,"Enter integer",NULL};
struct Gadget igadget={NULL,28,29,307,10,GADGHCOMP,RELVERIFY|LONGINT,
                       STRGADGET,(APTR)&iborder,NULL,&iprompt,0,
                       (APTR)&igadg,1,NULL};

/* define the OK! gadget */

USHORT opts[]={0,0,54,0,54,22,0,22,0,0};
struct Border oborder={-2,-1,6,0,JAM1,5,opts,NULL};
struct IntuiText oprompt={3,0,JAM2,16,5,NULL,"OK!",NULL};
struct Gadget ogadget={NULL,38,86,51,21,GADGHCOMP,RELVERIFY,BOOLGADGET,
                    (APTR)&oborder,NULL,&oprompt,0,NULL,1,NULL};

/* define the cancel gadget */
```

Listing 5-10. (cont.)

```
USHORT cpts[]={0,0,54,0,54,22,0,22,0,0};
struct Border cborder={-2,-1,5,0,JAM1,5,cpts,NULL };
struct IntuiText cprompt={3,0,JAM2,3,6,NULL,"Cancel",NULL};
struct Gadget cgadget={NULL,268,86,51,21,GADGHCOMP,RELVERIFY,BOOLGADGET,
                    (APTR)&cborder,NULL,&cprompt,0,NULL,3,NULL};

/* define the window that will encompass all three gadgets */

struct NewWindow NewWindow={154,29,399,138,0,1,ACTIVEWINDOW|GADGETUP,NULL,
                        NULL,NULL,NULL,NULL,NULL,5,5,640,200,
                            WBENCHSCREEN};

/* get_prop() will create a triple of gadgets: a proportional one and two
              booleans. The value of the proportional gadget will only be
              returned, if the OK! boolean gadget is selected. Selection
              of the OK! gadget generates a return value of 1 while the
              Cancel gadget will produce a 0. */

get_prop(hval,vval,scrn)
USHORT *hval,*vval;
struct Screen *scrn;
{
 struct Window *window;

 int rvalue;

 NewWindow.Screen=(scrn == NULL) ? WBENCHSCREEN : scrn;

 ogadget.NextGadget=&cgadget;      /* set up the chain of gadgets */
 pgadget.NextGadget=&ogadget;

 NewWindow.FirstGadget=&pgadget;   /* set the first gadget in the window */

 window=(struct Window *)OpenWindow(&NewWindow);

 rvalue=get_flag(window);

 *hval=pgadg.HorizPot;             /* prepare to report the values */
 *vval=pgadg.VertPot;

 CloseWindow(window);
 return rvalue;
}

/* get_string() will create three gadgets: a string gadget and two
                boolean ones. The function returns 1, if the OK! gadget was
                selected, 0 for the Cancel. The value of the string gadget
                will only be returned, if the OK! boolean gadget is
                selected.*/

get_string(buffer,scrn)
char *buffer;
struct Screen *scrn;
```

Listing 5-10. (cont.)

```
{
 struct Window *window;

 int rvalue;

 sgadg.Buffer=buffer;

 NewWindow.Screen=(scrn == NULL) ? WBENCHSCREEN : scrn;

 ogadget.NextGadget=&cgadget;              /* create the chain of gadgets */
 sgadget.NextGadget=&ogadget;

 NewWindow.FirstGadget=&sgadget;           /* put the chain in the window */
 window=(struct Window *)OpenWindow(&NewWindow);

 rvalue=get_flag(window);

 CloseWindow(window);
 return rvalue;
}


get_int(value,scrn)
LONG *value;
struct Screen *scrn;
{
 struct Window *window;


 static char buffer[80]="0";
 int rvalue;
 igadg.Buffer=buffer;

 NewWindow.Screen=(scrn == NULL) ? WBENCHSCREEN : scrn;

 ogadget.NextGadget=&cgadget;       /* create a chain of 3 gadgets */
 igadget.NextGadget=&ogadget;

 NewWindow.FirstGadget=&igadget;    /* initialize the NewWindow structure */
 window=(struct Window *)OpenWindow(&NewWindow);

 rvalue=get_flag(window);           /* get the OK!/Cancel message */
 *value=igadg.LongInt;              /* return the parameter value */

 CloseWindow(window);
 return rvalue;
}

/* get_flag() will handle i/o from the OK! and Cancel gadgets which are
              common to the functions. */

get_flag(window)
```

Listing 5-10. (cont.)

```
struct Window *window;
{
 struct IntuiMessage *msg,*GetMsg();
 int flag=-1;
 for(;;) {
  Wait(1 << window->UserPort->mp_SigBit);
  while((msg=GetMsg(window->UserPort))) {
    if(msg->Class == GADGETUP)              /* capture a gadget message */
      if(msg->IAddress == (APTR)&ogadget) {  /* Ok! gadget selected. */
         ReplyMsg(msg);
         flag=1;
         break;
        }
       else if(msg->IAddress == (APTR)&cgadget) { /* Cancel gadget
                                                     picked */
         flag=0;
         ReplyMsg(msg);
         break;
       }
      }
     if(flag != -1)          /* if no pick, continue until there is one */
       break;
    }
 return flag;
}
```

The function *get_prop()* creates a proportional gadget and returns its values through the pointer variables hval and vval. The function itself returns the flag value generated by the pair of Boolean gadgets generated by a call to *get_flag()*. Note that the function first sets up a linked list of structures, places this in a NewWindow structure and opens a window. This window structure is closed just prior to the end of the function. The scrn parameter is a pointer to an enclosing screen or NULL to indicate the standard workbench screen. It should be noted that whichever Boolean gadget is chosen, the current value of the proportional gadget is returned.

Get_string() will also create a three way gadget setup within a window. In this case, however, a string gadget has the central honor. This string value is returned through the character pointer buffer. As before, the function returns a value that was extracted from a call to *get_value* and, at that point, returns the current value in buffer. *Get_int()* works in an analogous fashion, but here the long integer value is found in the LongInt field of the gadget structure and returned through the parameter value.

Once we have compiled this file to object form, whenever we wish to use these functions, we merely link this object file along with our main program file and all the other support files. The advantage of these functions is that they are ready to use just like the functions found in the standard library.

Listing 5-11 illustrates a simple program that can be used to test this gadget library.

Listing 5-11. A driver program to illustrate the gadget library.

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <lattice/stdio.h>

main()
{
 USHORT h,v;
 LONG x;
 char cmd,buffer[80];

 OpenAll();

 if(!get_prop(&h,&v,NULL))
   exit();
printf("horizontal=%u vertical=%u\n",h,v);
cmd=getchar();

 if(!get_string(buffer,NULL))
   exit();

 printf("buffer=%s\n",buffer);
 cmd=getchar();

 if(!get_int(&x,NULL))
   exit();

 printf("long value=%ld\n",x);
}
```

ROM Kernel Graphics Commands

Beneath Intuition, underlying and supporting it, is the executive kernel. This contains the most basic system calls and the essential multitasking support routines. This collection of software is often called the ROM kernel or the Exec kernel. Among the system services provided by this low-level kernel is a complete set of graphics and display routines. These are functions that directly interact with the specialized graphics chips that are a unique feature of the Amiga: the *blitter* and the *copper*. These routines work independently of Intuition—indeed they support it—but they can also be used within Intuition to create more efficient graphics displays.

The connecting link between Intuition and these routines is a basic structure of the graphics kernel, the *RastPort*. This is a specialized message port that allows communication with individual display areas. The RastPort is a fairly complex structure and a more basic one than a screen or a window, although in operation it is similar. Fortunately, Intuition opens and initializes

a RastPort for each screen and window that it opens. Access to these is found in the respective Intuition structures:

- For screens this is the *RastPort* field.
- For windows, it is *RPort*.

This greatly simplifies life for the programmer. It allows the creation of elaborate graphics displays without having to manage all the details of the display. What is more important, these graphics displays exist under the well-behaved rules of the Intuition interface. This is also a situation where a GIMMEZEROZERO or a backdrop window can be used to good effect.

Setting Up the RastPort

Each window or screen has its own RastPort structure. Within this structure are a number of fields which relate to the action of specific graphics kernel functions. It is sometimes necessary to set these fields and then pass the RastPort structure as a parameter to a particular function. These fields refer to certain actions within the graphics hardware, or set default values.

The first such set of values contains the drawing pens defined in the RastPort structure. These pens are pointers to one of the thirty-two color registers maintained by the Amiga to control the display. There are three pens:

- *FgPen* sets the primary drawing color.
- *BgPen* is the background color.
- *AOlPen* is the color used for area outlining.

Each one of these is set by a specific system function: *SetAPen()*, *SetBPen()*, and *SetOPen()* respectively. The format of each of these is identical. For example, to set the *FgPen*, call:

```
SetAPen(RPort,Color);
```

Here *RPort* is a pointer to a RastPort structure, and *Color* is a value which indicates a color register. The range over which *Color* can vary is dependent on the depth of the structure attached to *RPort*.

The format of a graphics display is set by the drawing mode. As with the Intuition-specific functions, this specifies the interplay between foreground and background colors. Four are possible:

- JAM1 replaces each pixel indicated by the color of the *FgPen*.
- JAM2 is more complicated, utilizing both *FgPen* and *BgPen* to produce a pattern.
- COMPLEMENT sets the pixels to their complement value.
- INVERSEVID draws text in a way that inverts its normal appearance.

These modes are set by a call to *SetDrMd()*. This has the general form:

```
SetDrMd(RPort,Mode);
```

Again, *RPort* is a pointer to a RastPort structure. *Mode* is one of the legal modes mentioned above—except in the case of INVERSVID, which can be combined with either JAM1 or JAM2 to produce different effects.

Drawing Support

Several graphics kernel functions are available to facilitate line drawing on the display.

```
Move(RPort,x,y)
```

repositions the drawing cursor from its current position to coordinates defined by x and y. *RPort* points to the RastPort of the object in which this movement is to take place. This is a positioning function; no output is shown. To draw a line between two points, use:

```
Draw(RPort,x,y);
```

Note that this has precisely the same form as the *Move()* function, but in this case a line is drawn connecting the current position with the new one. The cursor is also moved to the new point.

Draw() sketches its line in the color set by *FgPen*. To produce a series of multicolored lines, it is only necessary to combine this function with *SetAPen()*. Listing 5-12 illustrates a program that uses this combination to create bars of color in a window. The function *makebar()* draws a series of lines in a single color across the display. The number of vertical lines drawn is set by the parameter *lin*. The color of the line is also a parameter. The main program loops through sixteen colors, calling *makebar()* for each iteration.

Listing 5-12. The use of ROM kernel graphics routines in a window (running in Intuition).

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Window *NoBorder;
struct RastPort *r;
struct Screen *Scrn;

main()
{
 ULONG flags;
 SHORT x,y,w,h,d,c0,c1;
 USHORT mode;
 VOID delay_func(),OpenALL();
 int i,j;

 OpenALL();

 /*  ======Open a hi-res custom screen==== */
```

Listing 5-12. (cont.)

```
  y=0;
  w=640;
  h=400;
  d=4;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,NULL);

  /*  ======Open a borderless window======*/

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
  NoBorder=(struct Window *)
            make_window(x,y,w,h,NULL,flags,Scrn);

 /*   ======Draw some lines========= */

  r=NoBorder->RPort;

  j=0;

  for(i=0;i<=16;i++)  {
    make_bar(i,10,r,j);
    j+=10;
   }

 /*   ======Delay for a bit to show off the windows====== */

  delay_func(100);

 /* =========Close down the windows in order========*/

  delay_func(10);


  CloseWindow(NoBorder);

  CloseScreen(Scrn);
}

make_bar(col,lin,rast,y)
int col,lin;
struct RastPort *rast;
SHORT y;
{
 int j;

 SetAPen(rast,col);
 for(j=0;j<lin;j++) {
```

Listing 5-12. (cont.)

```
      Move(rast,10,y+j);
      Draw(rast,600,y+j);
   }
}
```

To draw a series of connected lines (a polygon), use:

```
PolyDraw(RPort, count, array);
```

This functions much as the *DrawBorder()* function found in Intuition. The coordinate for each vertex is placed in an array. This array is passed to the function, along with a count of the number of sides and a pointer to the RastPort structure of the enclosing device. This function uses *FgPen* to render the lines.

Listing 5-13. The PolyDraw() function, using ROM kernel graphics routines in a window (running in Intuition).

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Window *NoBorder;
struct GfxBase *GfxBase;
struct Screen *Scrn;

main()
{
 ULONG flags;
 SHORT x,y,w,h,d,c0,c1;
static SHORT poly[]={450,10,
                     600,75,
                     450,150,
                     150,150,
                      10,75,
                     150,10};
 USHORT mode;
 VOID delay_func(),OpenALL();

 OpenALL();

 /*  ======Open a hi-res custom screen==== */

  y=0;
  w=640;
  h=400;
  d=4;
  c0=0x00;
  c1=0x01;
  mode=HIRES;
```

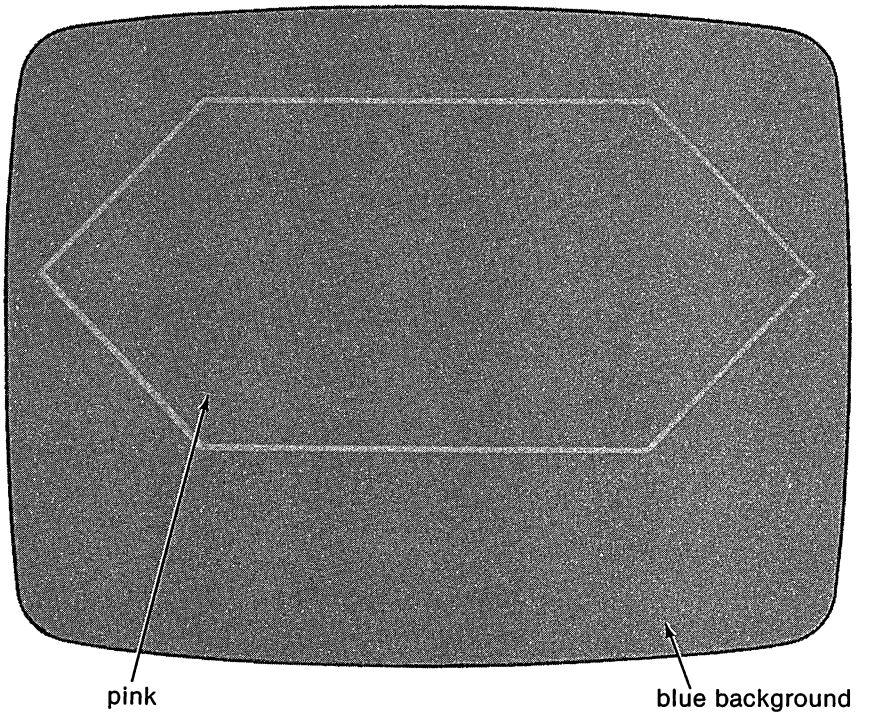
Listing 5-13. (cont.)

```
  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,NULL);

  /*  ======Open a borderless window======*/

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
  NoBorder=(struct Window *)
            make_window(x,y,w,h,NULL,flags,Scrn);

 /*   ======Draw some lines========= */

  r=NoBorder->RPort;

  SetAPen(r,5);
  Move(r,150,10);
  PolyDraw(r,6,poly);

 /*   ======Delay for a bit to show off the windows====== */

  delay_func(100);

 /* =========Close down the windows in order========*/

  delay_func(10);


  CloseWindow(NoBorder);

  CloseScreen(Scrn);
}

VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
```

In Listing 5-13 we use *PolyDraw()* to produce a figure in a window. The array *poly* contains the coordinate points for each vertex in our figure. We position the cursor at position 150,10 through a *Move()* function. *PolyDraw()* takes our initialized RastPort structure, the array of vertices, and the count of the sides of our figure, and draws it.

Figure 5-13 shows the result.

Figure 5-13. Output of Listing 5-13



With these three functions—*Move()*, *Draw()*, and *PolyDraw()*—it is necessary that the application do its own boundary checking. In each of these functions, if a point is specified that lies outside the bit map supplied by the RastPort structure, the results will be unpredictable.

In addition to the above functions, there are a pair of function calls that give you a handle on individual pixels:

```
ReadPixel(RPort,x,y);
```

This function returns an integer value—the value of the color found at that position—ranging from 0 to 255. If you specify a point outside the area defined as the display, a value of −1 is returned. The complementary function is:

```
WritePixel(RPort,x,y)
```

This puts a pixel at the specified *x,y* coordinate. *FgPen* supplies the color. A value of −1 returned by this function indicates an out-of-bounds condition for the coordinates. If the function call is successful, 0 is returned.

Area Fill

One of the most important of all graphics operations is filling an arbitrary polygon on the display with either a color or a pattern. The Amiga has this

capability built into its hardware—a feature which it shares with very expensive graphics work stations. This means that fill operations are done significantly faster than with systems where the work must be done in software. Access to this specialized hardware is through several system calls. Each of these calls allows you to do the fill operation in a slightly different way. The simplest fill operation allocates and fills a rectangle in the display with a specified color. The necessary function call for this operation is:

```
RectFill(Rport,xmin,ymin,xmax,ymax);
```

RPort is a pointer to the RastPort of the enclosing figure. *Xmin*, *ymin*, *xmax*, and *ymax* define a rectangle by specifying its upper left-hand and lower right-hand coordinates. The color used for the fill operation is dependent on the drawing mode and the three pens defined in the RastPort structure. In its simplest mode—JAM1—the color is a solid and only *FgPen* is used to render the display.

Listing 5-14 illustrates this simple case. Here we set the *FgPen* color through the *SetAPen()* function. A call to *RectFill()* produces a filled square with its upper left-hand corner at coordinate 10,10.

Listing 5-14. The RectFill() function, using ROM kernel graphics routines in a window (running in Intuition).

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/gfxmacros.h>

struct Window *NoBorder;
struct RastPort *r;
struct Screen *Scrn;

main()
{
 ULONG flags;
 SHORT x,y,w,h,d,c0,c1;
 USHORT mode;
 VOID delay_func(),OpenALL();

 OpenALL();

 /*  ======Open a hi-res custom screen==== */

  y=0;
  w=640;
  h=400;
  d=4;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,NULL);
```

Listing 5-14. (cont.)

```
  /*  ======Open a borderless window======*/

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
  NoBorder=(struct Window *)
           make_window(x,y,w,h,NULL,flags,Scrn);

 /*   ======Draw some lines========= */

  r=NoBorder->RPort;

  SetAPen(r,2);
  SetOPen(r,3);

  RectFill(r,10,10,100,100);

 /*   ======Delay for a bit to show off the windows====== */

  delay_func(100);

 /* =========Close down the windows in order========*/

  delay_func(10);


  CloseWindow(NoBorder);

  CloseScreen(Scrn);
}

VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

A true polygon fill can be accomplished by using the *AreaMove()* and *AreaDraw()* functions, but these, in turn, are dependent on two structures associated with the RastPort of the enclosing object—either screen or window. The first of these is *AreaInfo*. This structure sets up a buffer to store information about the figure that is being created by the fill functions. It is initialized by a call to:

```
InitArea(AInfo,buffer,count);
```

AInfo points to an AreaInfo structure; *buffer* is a pointer to a storage area for the figure being drawn, and *count* indicates the size of the figure in question. *Buffer* holds, temporarily, the coordinates of the vertices that define the polygon. As a rule of thumb, you need to set aside about five bytes of storage space per vertex. *AInfo* is assigned to the *AreaInfo* field of the RastPort structure.

Once you have a storage space for the parameters of your figure, you must allocate a workspace for the drawing routines themselves. This is accomplished by declaring a TmpRas structure. This is usually set to the full size of the screen— 200 by 320 in low-resolution and 200 by 640 in high-resolution mode. This space is set aside by a call to:

```
InitTmpRas(TRas,buffer,size);
```

Here *TRas* is a pointer to a TmpRas structure, *buffer* points to a block of memory; and *size* is an integer indicating the size of the buffer area. The *TmpRas* field of the RastPort structure is set to the address returned by this function.

With the initialization of these two workspaces, it is possible to define an arbitrary area to be filled. The first function to be called is:

```
AreaMove(RPort,x,y);
```

This function performs a dual service. It closes any pending polygon by connecting its last drawn coordinate to its initial point. The position *x,y* is recorded in the previously defined buffer and a new figure is started. A call to:

```
AreaDraw(RPort,x,y)
```

stores new *x,y* coordinates in this buffer. Note that nothing has been rendered on the display at this point. A final call to:

```
AreaEnd(RPort)
```

terminates the figure and also causes it to appear on the display monitor.

Listing 5-15. Area fill, using ROM kernel graphics routines in a window (running in Intuition).

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/gfxmacros.h>

struct Window *NoBorder;
struct RastPort *r;
struct Screen *Scrn;
struct TmpRas TRas;
struct AreaInfo AInfo;
```

Listing 5-15. (cont.)

```
main()
{
 ULONG flags;
 SHORT x,y,w,h,d,c0,c1;
 static SHORT Buffer[500];

 USHORT mode;
 VOID delay_func(),OpenALL();

 OpenALL();

 /*  ======Open a hi-res custom screen==== */

  y=0;
  w=640;
  h=400;
  d=4;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,NULL);

  /*  ======Open a borderless window======*/

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
  NoBorder=(struct Window *)
            make_window(x,y,w,h,NULL,flags,Scrn);

/*   ======Draw some lines========= */

  r=NoBorder->RPort;

  InitArea(&AInfo,Buffer,200);

  r->AreaInfo=&AInfo;
  r->TmpRas=(struct TmpRas *)
        InitTmpRas(&TRas,AllocRaster(320,200),RASSIZE(320,200));

  AreaMove(r,0,0);
  AreaDraw(r,75,0);
  AreaDraw(r,75,75);
  AreaDraw(r,0,75);
  AreaEnd(r);


/*   ======Delay for a bit to show off the windows====== */

  delay_func(100);
```

Listing 5-15. (cont.)

```
 /* =========Close down the windows in order========*/

  delay_func(10);


  CloseWindow(NoBorder);

  CloseScreen(Scrn);
}

VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Listing 5-15 shows the production of a simple figure. We use the RastPort pointer supplied by the open window, and we set aside 200 bytes to draw a four-sided figure—more than enough. A series of *AreaDraw()* function calls, bracketed by an *AreaMove()* and an *AreaEnd()*, completes the picture.

Listing 5-16. Area fill with outlining, using ROM kernel graphics routines in a window (running in Intuition).

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/gfxmacros.h>

struct Window *NoBorder;
struct RastPort *r;
struct Screen *Scrn;
struct TmpRas TRas;
struct AreaInfo AInfo;

main()
{
 ULONG flags;
 SHORT x,y,w,h,d,c0,c1;
 static SHORT Buffer[500];

 USHORT mode;
 VOID delay_func(),OpenALL();

 OpenALL();
```

Listing 5-16. (cont.)

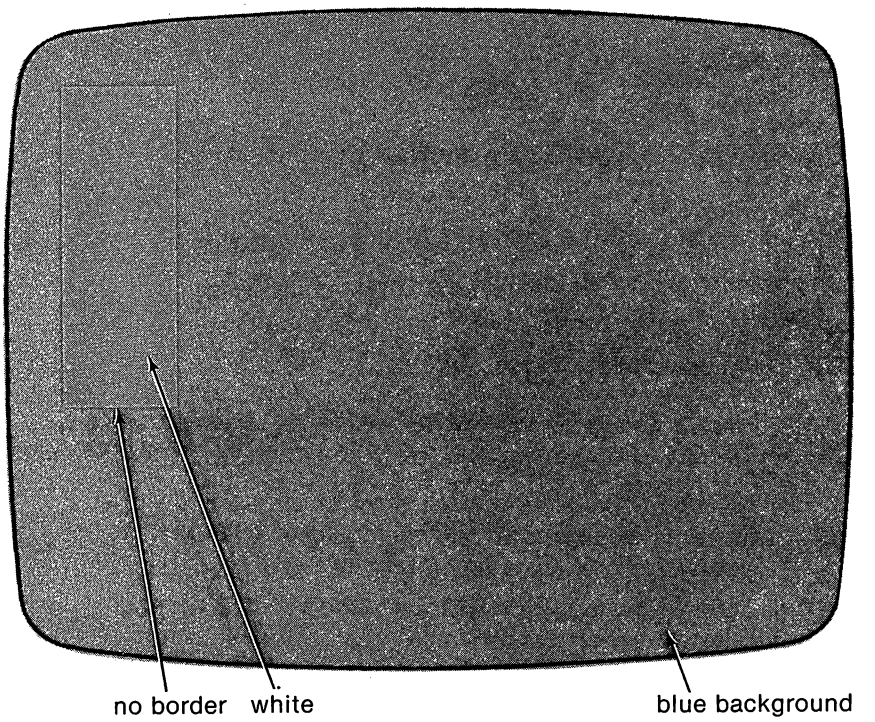
```
 /*  ======Open a hi-res custom screen==== */

  y=0;
  w=640;
  h=400;
  d=4;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,NULL);

  /*  ======Open a borderless window======*/

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
  NoBorder=(struct Window *)
            make_window(x,y,w,h,NULL,flags,Scrn);

 /*   ======Draw some lines========= */

  r=NoBorder->RPort;

  InitArea(&AInfo,Buffer,200);

  r->AreaInfo=&AInfo;
  r->TmpRas=(struct TmpRas *)
        InitTmpRas(&TRas,AllocRaster(320,200),RASSIZE(320,200));

  SetOPen(r,3);

  AreaMove(r,0,0);
  AreaDraw(r,75,0);
  AreaDraw(r,75,75);
  AreaDraw(r,0,75);
  AreaEnd(r);


 /*   ======Delay for a bit to show off the windows====== */

  delay_func(100);

 /* =========Close down the windows in order========*/

  delay_func(10);


  CloseWindow(NoBorder);

  CloseScreen(Scrn);
}
```

Listing 5-16. (cont.)

```
VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

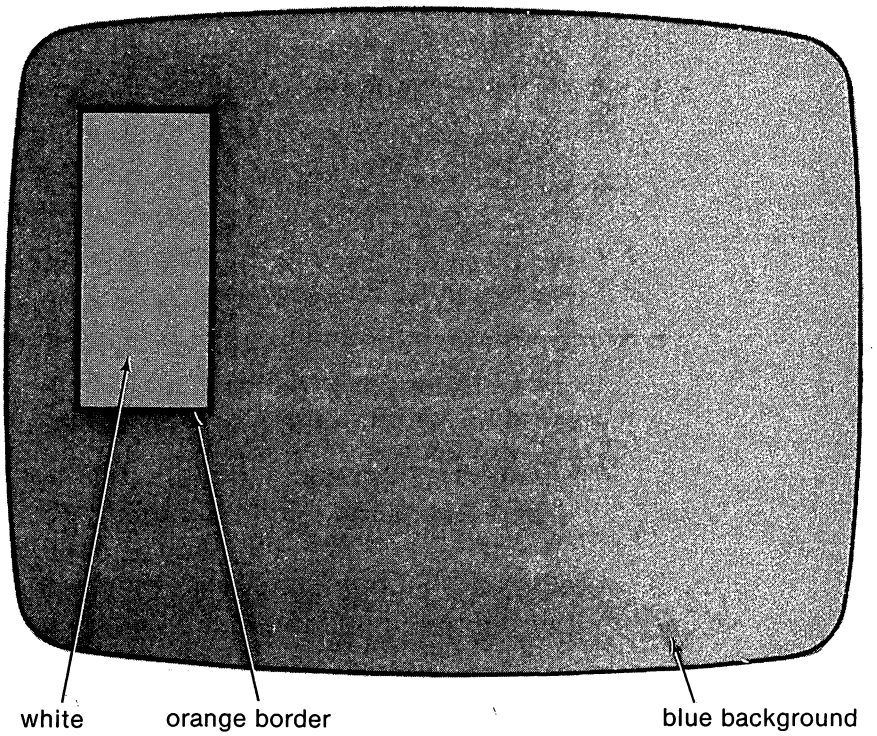
Listing 5-16 shows an interesting variation. By setting the *AOlPen* to a contrasting color, we produce a filled figure that is also outlined. Figures 5-14 and 5-15 show the results of these two examples.

Figure 5-14. Output of Listing 5-15



The area fill routines that we have used so far both create and fill a figure with color. It is sometimes necessary to draw a figure so that it appears on the screen or window in outline form, and then fill it. This is

Figure 5-15. Output of Listing 5-15



accomplished by using the *Flood()* function of the graphics library. This function has the form:

```
Flood(RPort,mode,x,y)
```

Here x and y define a point within an already drawn figure, and *mode* specifies one of two filling modes.

- If mode is equal to 0, each pixel in the area encompassed by the figure is compared to the color in the *AOlPen*. If it is different from this color, it is changed to that of the *FgPen*. This is *Outline Mode*.
- *Color Mode* is indicated by a value of 1 for the mode variable. This takes the color at the x and y coordinates used as a parameter. Each pixel with the same color as this initial point is replaced with the color in *FgPen*.

Flood() is illustrated by Listing 5-17. Here we use the *Draw()* and *Move* commands to create a rectangle in the NoBorder Window. We use the *Flood()* function to fill that rectangle. Figure 5-16 shows the output from this program.

Listing 5-17. Flood fill, using ROM kernel graphics routines in a window (running in Intuition).

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/gfxmacros.h>

struct Window *NoBorder;
struct RastPort *r;
struct Screen *Scrn;

main()
{
 ULONG flags;
 SHORT x,y,w,h,d,c0,c1;
 USHORT mode;
 VOID delay_func(),OpenALL();
 BYTE Fpen;

 OpenALL();

 /*  ======Open a hi-res custom screen==== */

  y=0;
  w=640;
  h=400;
  d=4;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,NULL);

  /*  ======Open a borderless window=======*/

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
  NoBorder=(struct Window *)
            make_window(x,y,w,h,NULL,flags,Scrn);

 /*   ======Draw some lines========= */

  r=NoBorder->RPort;
  SetOPen(r,3);

  SetAPen(r,r->AOlPen);
  Move(r,0,0);
  Draw(r,100,0);
  Draw(r,100,100);
  Draw(r,0,100);
  Draw(r,0,0);
  SetAPen(r,3);
  Flood(r,0,10,50);
```

Listing 5-17. (cont.)

```
 /*   ======Delay for a bit to show off the windows====== */

  delay_func(100);

 /* =========Close down the windows in order========*/

  delay_func(10);


  CloseWindow(NoBorder);

  CloseScreen(Scrn);
}

VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Filling with a Pattern

The RastPort structure contains two fields that support the use of patterns with graphics objects.

1. You can specify a line drawing pattern that will allow you to create various forms of dotted or dashed lines.
2. You can specify an area fill pattern and use it in place of a solid color during a fill operation.

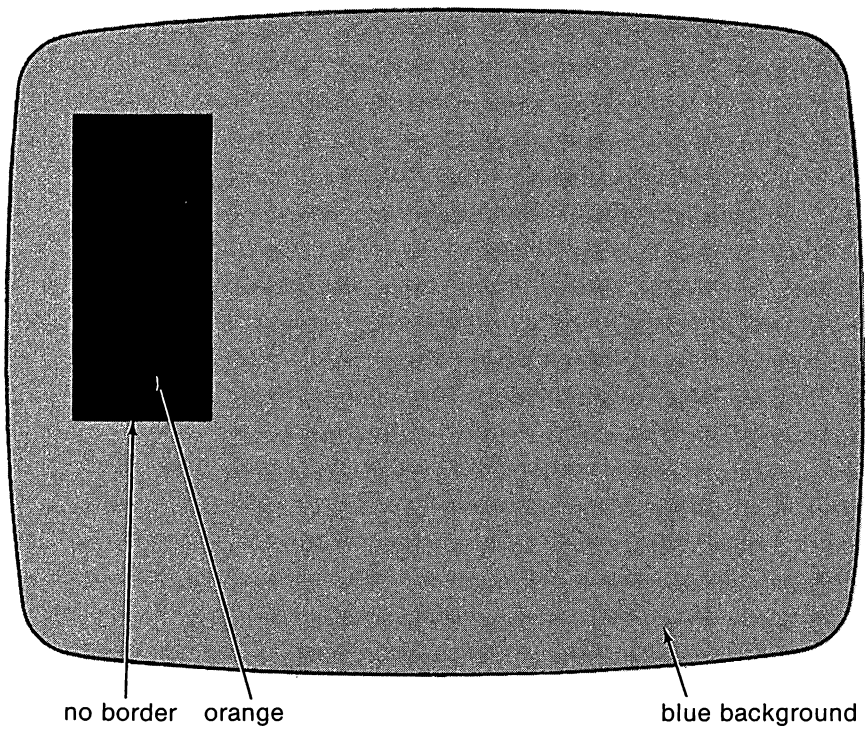
These capabilities are controlled by two macros: *SetDrPt()* and *SetAfPt()*. These macros are found in the header file *graphics/gfxmacros.h*. This file must be explicitly included before the definition of any function or program that is to do pattern fill.

The simplest form of pattern drawing is that of a line. The line pattern is a 16-bit quantity, applied to all lines controlled by the RastPort. The pattern can be set or reset at any time via the macro command:

```
SetDrPt(RPort,pattern);
```

Pattern is a number, usually specified in hexadecimal, which indicates

Figure 5-16. Output of Listing 5-17



the form of the line pattern. For example, *0xffff* represents the bit pattern, 1111111111111111. This is a solid line, the default condition when the RastPort is initially opened. A value of 1 in a bit position forces the line drawing routines to put in a solid section; a 0, a blank space. The bit pattern 0101111101011111, indicates a more complex pattern; it would be specified by the number *0x5f5f*. Area pattern fill requires a more complex operation. An area pattern is a rectangle sixteen bits wide, but it can be any height as long as the height is a power of two. Thus, you can create a pattern that is 1, 2, 4, 8, or any higher power of two. This pattern can then be used to fill a figure in place of the solid color used above.

An area fill pattern is defined in an array. Each member of the array represents one line of the pattern. A 1 bit indicates that a pixel will be drawn. A 0 bit defines that space as an empty area. Once you have defined this pattern, you can call the macro:

```
SetAfPt(RPort,PatArray,Size);
```

PatArray is a pointer to the array just defined containing the pattern, and *Size* indicates indirectly how many lines you have defined within the pattern. This value is the power of two that indicates this quantity. Once you have executed this setup procedure, whenever you specify a fill operation, this pattern will be used.

Listing 5-18. The RectFill() function with a pattern, using ROM kernel graphics routines in a window (running in Intuition).

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/gfxmacros.h>

struct Window *NoBorder;
struct RastPort *r;
struct Screen *Scrn;

USHORT pat[]={ 0xff00,
               0xff00,
               0x00ff,
               0x00ff,
               0xf0f0,
               0xf0f0,
               0x0f0f,
               0x0f0f};

main()
{
 ULONG flags;
 SHORT x,y,w,h,d,c0,c1;
 USHORT mode;
 VOID delay_func(),OpenALL();

 OpenALL();

 /*  ======Open a hi-res custom screen==== */

  y=0;
  w=640;
  h=400;
  d=4;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,NULL);

  /*  ======Open a borderless window======*/

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
  NoBorder=(struct Window *)
            make_window(x,y,w,h,NULL,flags,Scrn);

 /*   ======Draw some lines========= */

  r=NoBorder->RPort;
```

Listing 5-18. (cont.)

```
  SetAPen(r,2);
  SetOPen(r,3);
  SetBPen(r,4);

  SetAfPt(r,pat,3);
  SetDrMd(r,JAM2);

  RectFill(r,10,10,100,100);

 /*   ======Delay for a bit to show off the windows====== */

  delay_func(100);

 /* =========Close down the windows in order========*/

  delay_func(10);


  CloseWindow(NoBorder);

  CloseScreen(Scrn);
}

VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

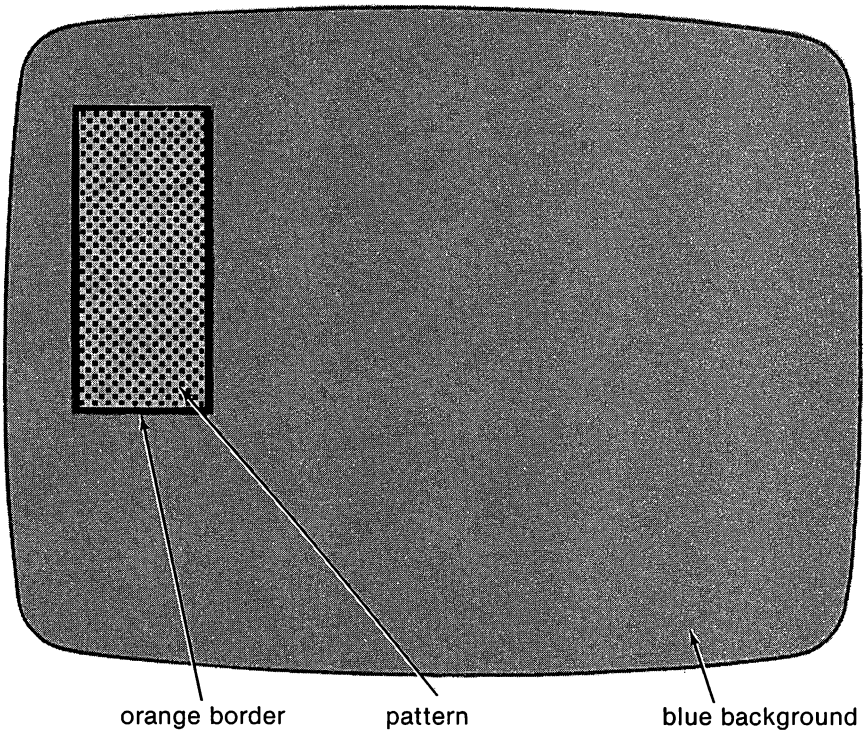
Pattern fill is shown in Listing 5-18 and Figure 5-17. Here we set up a pattern using the *SetAfPt()* macro and do a rectangle fill. Note that we set the drawing mode to JAM2; this will render the pattern using the *FgPen* to color the 1 bits and the *BgPen* to draw the 0 bit positions.

Some Miscellaneous Functions

We will close out this chapter by turning attention to two functions that are simple to use, yet offer a high level of convenience to the graphics programmer.

```
SetRast(RPort,Pen)
```

Figure 5-17. Output of Listing 5-18



sets the entire raster display to the color of the pen specified by the *Pen* parameter. Listing 5-19 illustrates the use of this function. We set *FgPen* to point to a specific color register and pass it to the function, along with a pointer to the RastPort structure. The result, shown in Figure 5-18, is a change to that color for the entire display. This function can be used to make such a global change quickly.

Listing 5-19. SetRast() function, using ROM kernel graphics routines in a window (running in Intuition).

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/gfxmacros.h>

struct Window *NoBorder;
struct RastPort *r;
struct Screen *Scrn;

main()
{
 ULONG flags;
 SHORT x,y,w,h,d,c0,c1;
```

Listing 5-19. (cont.)

```
 USHORT mode;
 VOID delay_func(),OpenALL();

 OpenALL();

 /*  ======Open a hi-res custom screen==== */

  y=0;
  w=640;
  h=400;
  d=4;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,NULL);

  /*  ======Open a borderless window======*/

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
  NoBorder=(struct Window *)
            make_window(x,y,w,h,NULL,flags,Scrn);

 /*   ======Draw some lines========= */

  r=NoBorder->RPort;

  SetAPen(r,3);
  SetRast(r,r->FgPen);


 /*   ======Delay for a bit to show off the windows====== */

  delay_func(100);

 /* =========Close down the windows in order========*/

  delay_func(10);


  CloseWindow(NoBorder);

  CloseScreen(Scrn);
}

VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;
```

Listing 5-19. (cont.)

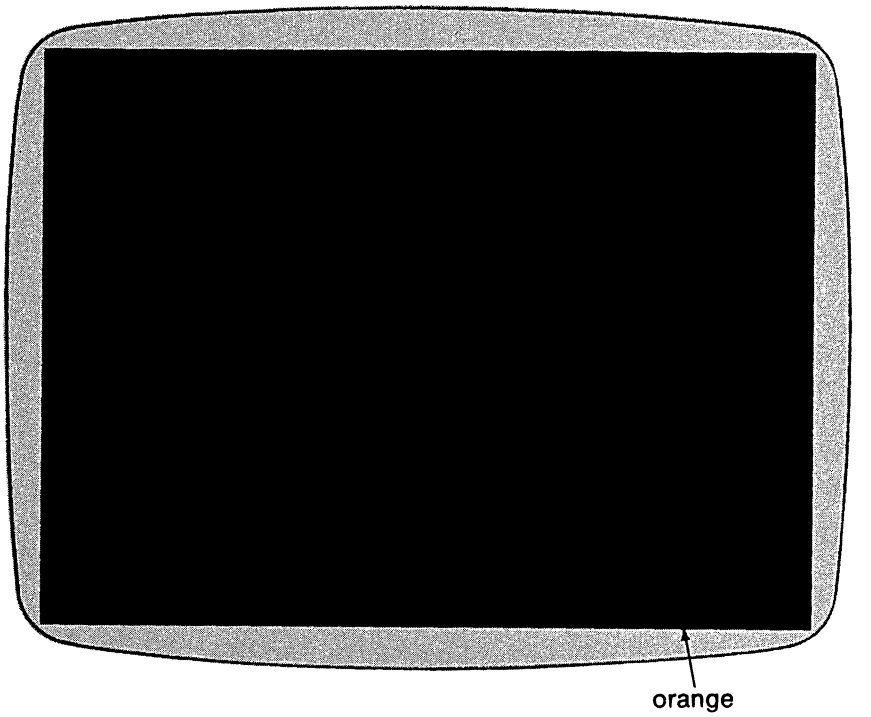
```
 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Listing 5-21 illustrates another simple yet powerful function:

```
ScrollRaster(RPort,delta_x,delta_y,xmin,ymin,xmax,ymax)
```

This causes a section of the display attached to the specified RastPort structure to scroll in either a horizontal direction, a vertical direction, or both. The area over which this scrolling takes place is defined by the variables *xmin,ymin,xmax,ymax*. *Delta_x* and *delta_y* indicate the incremental change in the position of the display. Areas vacated by the objects in the display are replaced by the background color. Figure 5-19 shows the output from this example.

Figure 5-18. Output of Listing 5-19



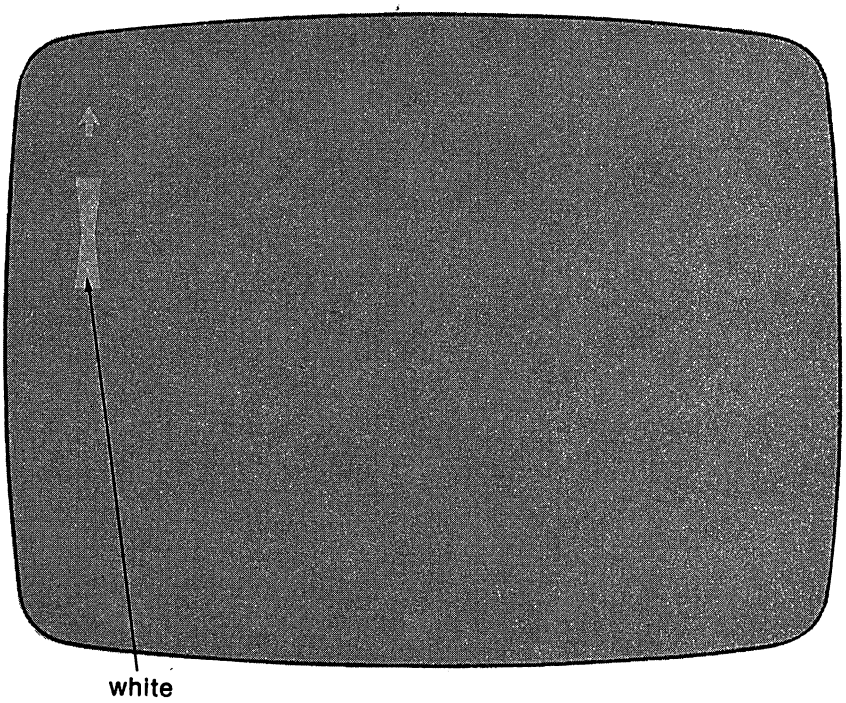
Listing 5-20. The ScrollRaster() function, using ROM kernel graphics routines in a window (running in Intuition).

```
#include <exec/types.h>
#include <intuition/intuition.h>

struct Window *NoBorder;
struct RastPort *r;

USHORT imagepts[]={0xffff,0x4ffe,0x3ffc,0x1ff8,
                   0x0ff0,0x07e0,0x03c0,0x03c0,
                   0x03c0,0x03c0,0x07f0,0x0ff0,
                   0x1ff8,0x3ffc,0x4ffe,0xffff};


struct Image picture={0,0,
                      16,16,
                      3,
                      NULL,
                      0x0001,0x0000,
                      NULL};

main()
{
 ULONG flags;
 SHORT x,y,w,h;
 VOID delay_func(),OpenALL();
 int i;

 OpenALL();

 /*  ======Open a borderless window===== */

  x=y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
  NoBorder=(struct Window *)make_window(x,y,w,h,NULL,flags);


/*  ======Create an image structure============== */

  picture.ImageData=imagepts;

  r=NoBorder->RPort;

  DrawImage(r,&picture,50,50);

  delay_func(10);

  for(i=0;i<50;i++)
    ScrollRaster(r,0,1,10,10,100,100);

/* ========Delay for a bit to show off the windows======== */

  delay_func(100);
```

Listing 5-20. (cont.)

```
/* ========Close down the windows in order=========*/

  delay_func(10);


  CloseWindow(NoBorder);
}


VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Figure 5-19. Output of Listing 5-20



A Simple Drawing Program

As a practical exercise calculated to draw together many of the topics we've discussed in this chapter, we can create a simple, minimal drawing program. This program opens a custom screen and a small window. By manipulating the mouse and the mouse buttons, the user can either draw a line or move the cursor without drawing. A further refinement allows the user to turn the draw capability on or off from a menu. As in earlier examples we will spread our new functions over several files to implement a structured design.

Listing 5-21 illustrates the main support function, *get_mouse()*. This function accepts a window reference and traps the significant events within that window. These events include the pressing of either mouse button, a click on the close window gadget, menu pick event, or even the movement of the mouse; each one of these is reported back to the calling function. A MOUSEBUTTONS event returns the select code for the specific button pushed. A MOUSEMOVE event returns this code as well, but also reports the position of the mouse through the reference parameters x and y. A MENUPICK returns a flag value to indicate this activity. The specific menu item picked is assigned to the mflag parameter. If the user picks the close window gadget, the window is closed within the *get_mouse()* function and a specific flag value is returned.

Listing 5-21. Illustrating a get_mouse() function.

```
#include <exec/types.h>
#include <intuition/intuition.h>

#define EOLW 2                                    /* define special flags */
#define MPICK 9
USHORT get_mouse(window,x,y,mflag)
struct Window *window;
SHORT *x,*y;
USHORT *mflag;
{
 int flag=0;
 USHORT select;
 struct IntuiMessage *msg,*GetMsg();    /* set up a IDCMP message object */

 for(;;) {
   Wait(1 << window->UserPort->mp_SigBit);

   while((msg=GetMsg(window->UserPort))) {
     switch (msg->Class) {
        case CLOSEWINDOW  : ReplyMsg(msg);       /* capture window close */
                            flag=EOLW;
                            break;
        case MOUSEBUTTONS : select=msg->Code;    /* mouse button handler */
                            ReplyMsg(msg);
                            return select;
        case MOUSEMOVE    : *x=msg->MouseX;      /* the mouse has moved */
                            *y=msg->MouseY;
                            select=msg->Code;
```

Listing 5-21. (cont.)

```
                        ReplyMsg(msg);
                        return select;
        case MENUPICK   : ReplyMsg(msg);       /* trap a menu choice */
                        *mflag=msg->Code;
                        return MPICK;
    }
   if(flag == EOLW) {                          /* window close handler */
     CloseWindow(window);
     return EOLW;
   }
  }
 }
}
```

The *main()* function for the draw program can be found in Listing 5-22. In this function, we must open Intuition, set up and open both a custom screen and a window, and set the menu strip in that window. Note the use of the ModifyIDCMP() system function to prepare the already opened window to report on mouse and menu activity. By using this function, we can use our previously defined window support function without modifications—another structured technique that helps the programmer develop clear, easy to follow code.

Listing 5-22. An example of a simple drawing program.

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include "m_sup.h"                  /* include the menu definitions */

#define MPICK 9                       /* define some special flags */
#define EOLW 2

struct Screen *Screen;
struct Window *Window;
void wputs();

main()
{
 USHORT flag,button=SELECTUP,get_mouse(),item_id=1,mflag,
        iflags=CLOSEWINDOW|VANILLAKEY|MOUSEMOVE|MOUSEBUTTONS|MENUPICK;
 ULONG wflags=WINDOWSIZING|WINDOWDRAG|WINDOWDEPTH|
                          WINDOWCLOSE|SMART_REFRESH|REPORTMOUSE|ACTIVATE;
 SHORT x,y;

 OpenAll();

 Screen=(struct Screen *)
          make_screen(0,640,200,3,0,1,HIRES,"The Art Show");

 Window=(struct Window *)
           make_window(20,20,300,100,"Draw or Shoot",wflags,0,1,Screen);
```

Listing 5-22. (cont.)

```
 ModifyIDCMP(Window,iflags);                          /* set window options */

 SetMenuStrip(Window,&menu);                           /* set up the menus */

 for(;;)  {
    if((flag=get_mouse(Window,&x,&y,&mflag)) == EOLW) {
      CloseScreen(Screen);
      exit(TRUE);
   }
  button=(flag == SELECTUP) || (flag == SELECTDOWN) ? flag : button;
  if(flag == MPICK)                                  /* capture menu events */
    item_id=ITEMNUM(mflag);

  if(button == SELECTDOWN && item_id == 0)           /* draw option */
     Draw(Window->RPort,x,y);
  else if(button == SELECTUP || item_id ==1)         /* move option */
     Move(Window->RPort,x,y);
 }
}
```

The main body of the function is a continuous loop that keeps querying the *get_mouse()* function. When a window close is reported, the screen is also removed and the program ends. MENUPICK and MOUSEBUTTON events are also checked for and handled by setting particular flags: button indicates the status of the left button and item_id to carry the last menu choice. Compound Boolean expressions containing these flags control calls of the *Draw()* and *Move()* functions. Notice that within this program, a MOUSEMOVE is treated the same as a MOUSEBUTTONS event—only the status of the buttons is noted.

Listing 5-23. A file containing the setup for a menu system.

```
/* set up the "Draw Disabled" option */

struct IntuiText prompt1={6,7,JAM2,0,1,NULL,"Draw Disabled",NULL};
struct MenuItem d_item={NULL,0,11,125,9,ITEMTEXT+ITEMENABLED+HIGHCOMP,0,
                    (APTR)&prompt1,NULL,NULL,NULL,0xFFFF};

/* initialize the "Draw Enabled" menu item */

struct IntuiText prompt2={6,7,JAM2,0,1,NULL,"Draw Enabled",NULL};
struct MenuItem e_item={&d_item,0,0,120,10,ITEMTEXT+ITEMENABLED+HIGHCOMP,0,
                    (APTR)&prompt2,NULL,NULL,NULL,0xFFFF};

/* create the menu structure */

struct Menu menu={NULL,0,0,84,0,MENUENABLED,"Options:",&e_item};
```

All of the menu setup information has been exported to a header file, m_sup.h. The content of this file is displayed in Listing 5-23. The necessary structures are both defined and initialized here. This is a reasonable approach and one that can also increase the structure of the program. A program with a different menu system can be quickly created just by altering the values in this support file. Minimal changes to the rest of the program would be necessary. Indeed, if the variable names are the same, it would only be necessary to recompile the file containing the *main()* function and include the other files in the linking stage.

This example program can be used as a springboard for experimentation. More functions can be added to enhance its operation. Using the previously defined library functions is a good illustration of modular technique.

Summary

In this chapter, we have explored the graphics capability of the Amiga, available to the programmer through Intuition. We have discussed the three graphics objects directly defined within the window interface: borders, IntuiText, and images. This represents a well-behaved interface that is both powerful and easy to use. With these objects and their corresponding functions, powerful graphics displays can be produced.

The Amiga does not stop with Intuition graphics. The underlying operating system software—the Exec ROM kernel—offers a complete graphics system, including drawing commands, area fill, and area pattern fill. We have explored these graphics functions, as they are accessible through the high-level interface Intuition.

Animating the Sprites

Chapter 6

Sprites
Defining a Sprite
Color and the Sprites
The Simple Sprite
Animating GELs Objects
Summary

The Amiga offers hardware support for animation; this comes in the form of *sprites*, graphics-oriented displays that can be moved independent of other objects in the display field. The format or the color of sprites can also be changed while they are being displayed. Although there are some restrictions on the shape and colors that constitute them, sprites offer a flexible alternative for movement and animation in a video display. In addition to these hardware resources, there is a software subsystem that facilitates the manipulation of the hardware resource.

Sprites

A sprite is a hardware object on the Amiga. There are eight special purpose DMA (direct memory access) channels that are used to define these graphics objects. This means that the drawing of these objects on the screen is independent of the main processor. Sprites can be drawn, moved, changed, and redrawn while the CPU is dealing with other tasks. Because they are supported directly this way and not built up through layers of software, sprites are fast, easy to program, and flexible in their use.

One of the most striking uses of a sprite—and one that well displays its flexibility—is the mouse cursor; this is sprite 0. Using a sprite as the cursor is necessary, because the cursor must be available across the entire display and not be stopped at window or screen boundaries. The hardware cursor is defined outside of all the Intuition objects, so that it can easily move between them. This is one example of sprite versatility. Other uses for these objects span the obvious and the not-so-obvious. Sprites are available for their traditional uses in video games, representing rockets, missiles, and the usual panoply of deadly devices. Since the shape of a sprite can be changed while it is being displayed, explosions and other forms of mayhem can easily be programmed into the display. Sprites can also have more mundane uses. They can serve as "paint brush" objects in drawing programs or "follow the bounc-

ing ball" pointers in a program devoted to music. There are many unanticipated applications wherein this kind of object can be used to effect. You are limited only by imagination.

Defining a Sprite

One restriction on the definition of a sprite is that its basic measurements are specified in terms of the normal or low-resolution display. The pixel is defined as:

1/320th the width of the screen; and

1/200th the height of the screen

However, since these objects are independently supported in hardware, their resolution is unaffected by that of any other objects that are on the display at the same time. Even if these objects change, the sprite remains the same. This is not hard to understand if you remember that a sprite is really only appearing in front of windows and screens, and is never really a part of them.

The width of a sprite is also restricted: it may be no more than sixteen pixels wide. A corresponding restriction is not in effect for height, which can be any value up to the full height of the display. Actually, a sprite can be higher than any screen or window that might be displayed behind it. In this case, the sprite must be scrolled to discover its full shape. Beyond these two restrictions, any shape that can be rendered into a space sixteen pixels wide can be implemented as a sprite.

The shape of a sprite is specified in memory as a set of contiguous 16-bit locations (Figure 6-1). The first two locations are reserved for hardware control instructions and represent the values to be put into the hardware registers associated with the sprite. The last two locations are also used for control. The body of this array is used to define the shape of the sprite. Each line is represented by two locations in memory. Each pixel in the display is defined by a pair of bits—one from each of the two words (Figure 6-2). This pair of bits indicates the color that a particular pixel will be. The color is specified indirectly through one or more color registers; these kinds of color specification will be discussed in more detail later.

The memory locations that define the sprite image are accessible through an array of 16-bit integers; either USHORT or UWORD will work. Typically, the appropriate values are indicated using hexadecimal numbers, since these make it easy to translate from bit positions to a numeric form that the system can understand. Figure 6-3 shows a typical way to create a sprite. First you create the figure in some convenient form such as graph paper. Once you have a form that you like, you can then translate each line of your drawing into a four-digit hexadecimal number (recall that four bits translate to one hexadecimal digit). Specification of the second word defining the line is a function of the color that you want for the individual pixel.

We mentioned earlier that the mouse cursor is actually a sprite. Intuition offers a function that allows you to change the shape of this cursor. This

Figure 6-1. The format of a sprite definition in memory

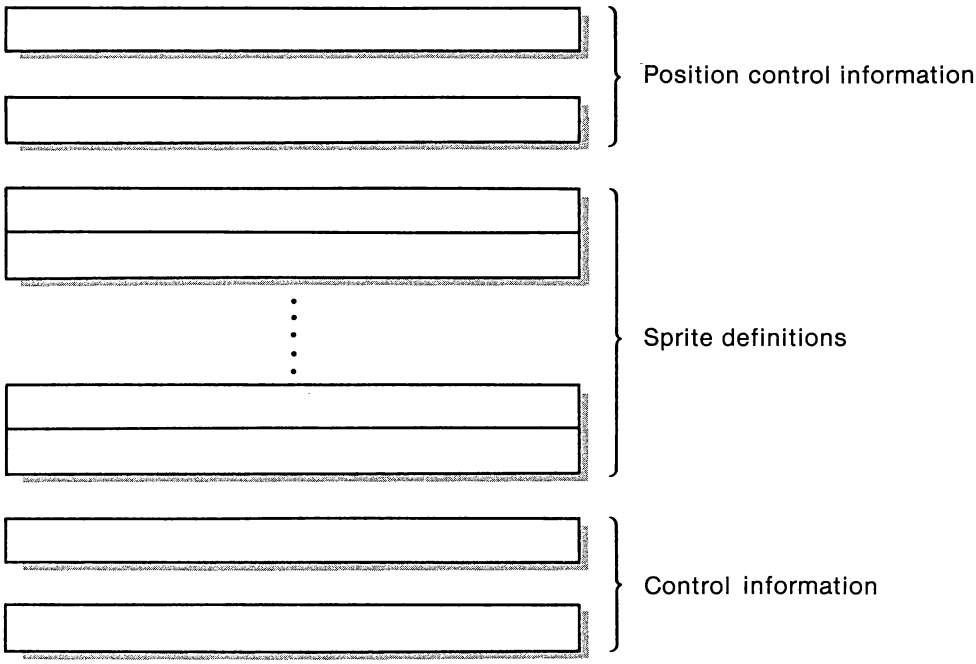


Figure 6-2. Defining the sprite image

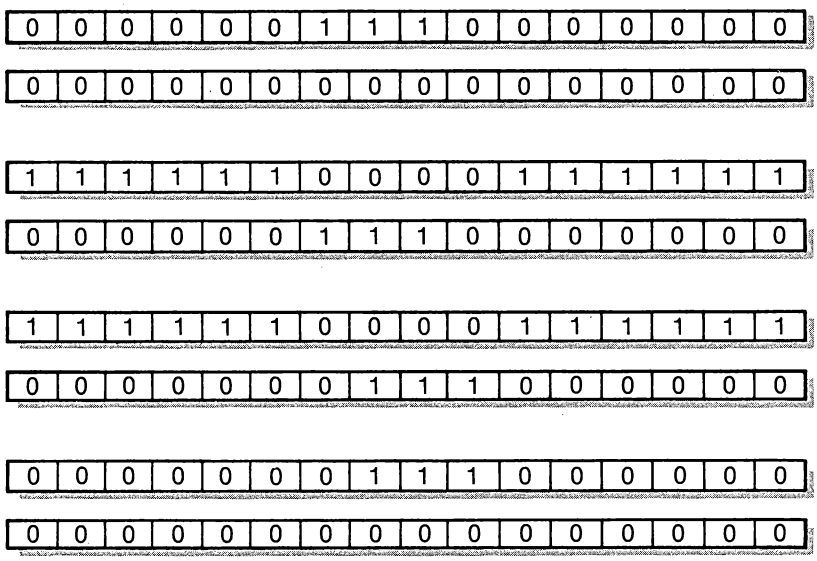
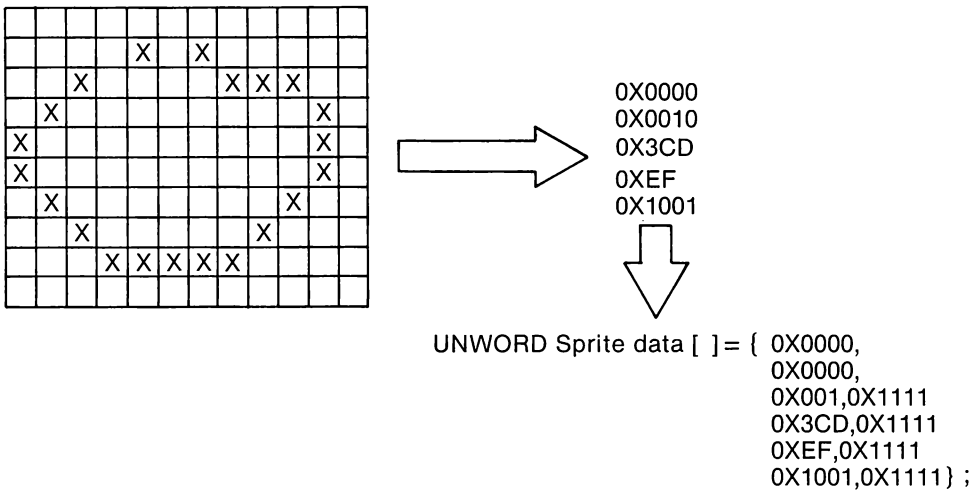


Figure 6-3. Translating a sprite image from graph paper to array



function, *SetPointer()* is tied to a particular window. Whenever the window is active, the new definition governs the shape of this cursor; when the window is deactivated, the cursor reverts to its original form. This is consistent with our claim that the sprite is independent of windows. The Intuition operating system senses the boundaries of software defined objects, such as windows, and in this case, changes the definition associated with the sprite. This can also be done under program command, which will be covered later.

The form of the command to alter the cursor is:

```
SetPointer(window,s_data,height,width,x,y)
```

where

window is a pointer to an open window.

s_data points to an array of 16-bit words.

height indicates the number of pixels in the y axis.

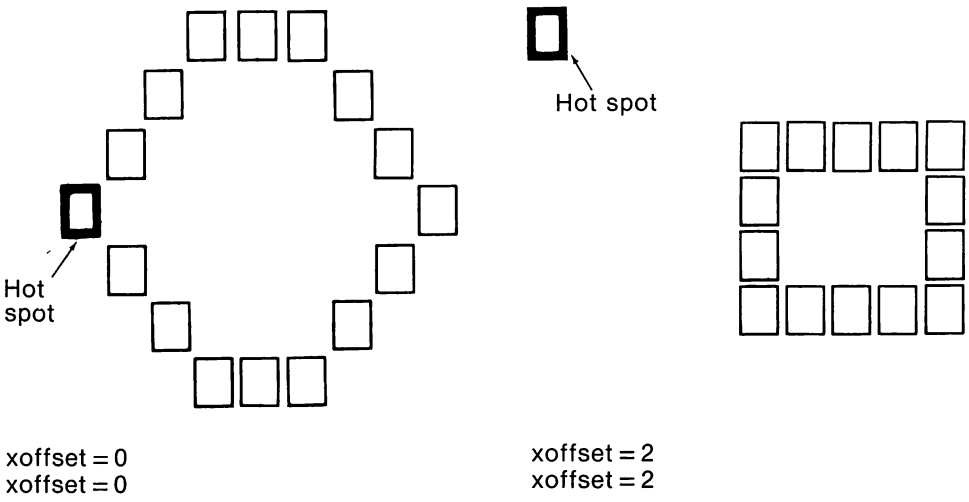
width indicates the size along the horizontal dimension.

x and y are the offsets from the cursor position box for the hot spot.

These last two parameters need some clarification. The action of the cursor is dependent on the position of a particular spot—called the *hot spot*—over the object to be chosen. The *x* and *y* value indicate the relationship of the shape of the cursor to this spot. Values of 0,0 place it at the upper left-hand corner (Figure 6-4). Note that any changes specified by *SetPointer()* occur immediately.

Listing 6-1 contains a program that uses the *SetPointer()* function. After opening a high-resolution screen and window, we use *SetPointer()* to change the shape of the cursor from its default value. The shape is defined in the

Figure 6-4. The hot spot and its relationship to xoffset and yoffset



array *imp_data*. For the sake of simplicity, we define a single color cursor. Note that the *x* and *y* offsets are both 0.

Listing 6-1. Use of SetPointer() to change the window pointer.

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/sprite.h>

struct Screen *Scrn;
struct Window *wind;

USHORT imp_data[]= {
   0x0000,0x0000,
   0x0180,0x0180,
   0x03c0,0x03c0,
   0x07e0,0x07e0,
   0x0e70,0x0e70,
   0x1c38,0x1c38,
   0x381c,0x381c,
   0x718e,0x718e,
   0xc3c3,0xc3c3,
   0xc3c3,0xc3c3,
   0x718e,0x718e,
   0x381c,0x381c,
   0x1c38,0x1c38,
   0x0e70,0x0e70,
   0x07e0,0x07e0,
   0x03c0,0x03c0,
   0x0180,0x0180,
   0x0000,0x0000,
```

Listing 6-1. (cont.)

```
   0x0000,0x0000 };

#define INTUITION_REV 29
#define GRAPHICS_REV 29

main()
{
 SHORT x,y,w,h,d;
 USHORT mode;
 ULONG flags;
 UBYTE c0,c1;
 VOID delay_func(),OpenALL();

  OpenALL(); /* Error checking could be added here */

 /*  ======Open a hi-res custom screen==== */

  y=0;
  w=640;
  h=200;
  d=3;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,"TEST SCREEN"); /* Error checking
                      could be added here */


 /* ===Open a window=== */

  x=10;
  y=10;
  w=300;
  h=150;
flags=ACTIVATE|SMART_REFRESH|WINDOWSIZING|WINDOWCLOSE|WINDOWDRAG;
  c0=-1;
  c1=-1;

  wind=(struct Window *)
         make_window(x,y,w,h,"Window 0",flags,c0,c1,Scrn,NULL);

 /* ===Create and set a new pointer=== */

  SetPointer(wind,imp_data,16,16,0,0);

  Delay(500);

 /* =========Close down the window then the screen==========*/

  CloseScreen(Scrn);

}
```

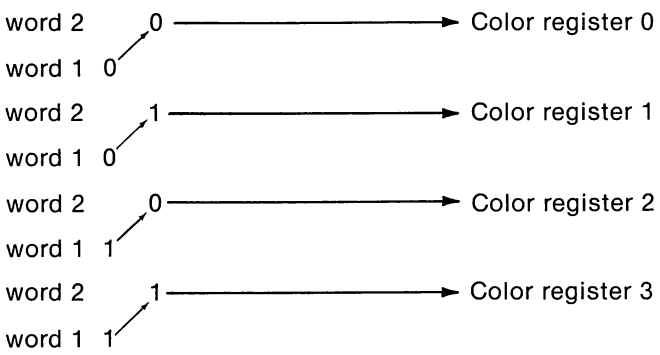
Listing 6-1. (cont.)

```
VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Color and the Sprites

We alluded to the fact that each pixel in the sprite is assigned a value that points to a color register. This indirect color addressing is the same throughout the Amiga for any kind of graphic image rendering. There is, however, a limitation on the sprite that is not found in the pure graphics routines. Each particular sprite is associated with a specific set of four-color registers. Each pixel in the sprite can take on one of three colors, or it can be transparent. In this latter case, the appearance of the sprite—or parts of the sprite—allow other objects to show through it. This allows the designer to make the sprite appear as if it were going behind an object. Recall that this object type is completely independent of windows and screens, and can contain no gadgets. Transparency is a way to capture the same kind of action that a window or screen provides with the Depth Arrangement Gadget.

Figure 6-5. Indirect addressing of color registers

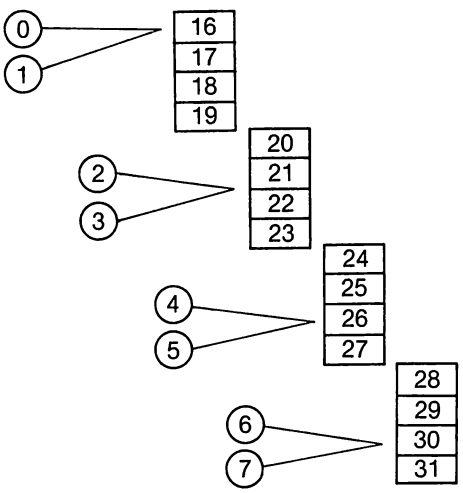


The color register identifier is encoded in the 2-bit specification for each pixel. (Recall that the sprite data array required two integers to define a

single line of the figure.) The 0 bits of each word are taken together, the 1 bits, and so on down to the sixteenth position. Within the three-color constraint, each pixel's color is independent of its neighbors. Figure 6-5 indicates how these color values are encoded.

Thirty-two color registers are available on the Amiga, numbered from 0 to 31. Each of these registers may specify any of the 4096 possible colors that can be produced. Any or all of the registers may be used by the graphics objects found in the display; this is a function of the specified depth of these objects. Sprites are assigned to the color registers 16 through 31; they do not necessarily have exclusive use of these registers. This is dependent on what is being displayed concurrently and the number of bit planes allocated. Some registers have to be shared with windows, screens, or pictures. Figure 6-6 indicates the specific assignment of registers to sprites.

Figure 6-6. Sprite color register map



There is a further complication. Sprites are divided into pairs, and each pair must share a register set. Setting a particular set of colors for sprite 0, for example, means that you are also setting the same colors for sprite 1.

The SimpleSprite

So far, you have seen how to specify the shape of a sprite, how to set the colors of its pixels, and what kind of memory organization the hardware expects. The Amiga also offers a software subsystem that lets you easily set up and manipulate these objects through C programs, without requiring access of the hardware register locations or even assembly language programming. This subsystem consists of the SimpleSprite structure and a series of system functions that manipulate it. This structure exists in addi-

tion to the array definition already used to good effect in the *SetPointer()* function. There are two system macros:

ON_SPRITE

OFF_SPRITE

These macros switch the sprite display circuitry on and off. The default condition is ON_SPRITE, so this need never be explicitly mentioned unless a previous execution of OFF_SPRITE has made the sprites invisible. These, along with other necessary declarations, are found in the header file *graphics/sprite.h*.

A SimpleSprite is defined by its structure declaration:

```
struct SimpleSprite {
   UWORD  *posctldata,
          height,
          x,y,
          num;
};
```

where

posctldata points to position control values in memory.

height indicates the number of lines in the sprite.

x,y set the sprite's current position in the display area.

num also contains hardware-specific information.

This is a very simple data type, particularly since only *height*, *x*, and *y* are set by the user. The other two members of the structure are set solely by the machine.

Once you have declared a SimpleSprite variable, you must ask the system to allocate a sprite for your use. This, too, is done through a system function:

```
sprite_id=GetSprite(s_ptr,s_number);
```

where

sprite_id is the number of the sprite allocated by this function.

s_ptr points to a SimpleSprite structure.

s_number indicates the number of the sprite desired.

A call to this function initializes the structure and prepares it to participate in the other sprite functions. If you specify −1 for the *s_number* parameter, the system assigns the next available sprite. In contrast, if you ask for a specific sprite, that one is allocated. If it is not available, the functions return −1 to indicate an error condition. This value is also returned if there are no sprites left to allocate.

Once a sprite has been allocated, it is necessary to set the desired values into the defining structure and to attach it to the image data. Setting the

initial values is easily accomplished by explicitly assigning values to the *x,y,* and *height* members. The *x* and *y* assignment set the initial position of the sprite. The *height* assignment must be consistent with the layout of the image data. Once you have made the *height* assignment—this is the only one that is strictly necessary—you can call the system to attach the data and sprite. This is done with:

```
ChangeSprite(v_port,s_struct,s_data)
```

where

v_port is a pointer to the ViewPort of the display area. This is commonly set to 0 to indicate the current value.

s_struct points to the SimpleSprite structure.

s_data is a pointer to the image data.

This function can be used again to change an existing sprite, by attaching a new image data array to it. The shape, the color, or both may be changed. The new sprite is visible immediately.

Besides adjusting a sprite's shape and color, it is also necessary to move it around the display. This is done by a call to:

```
MoveSprite(v_port,s_num,x,y)
```

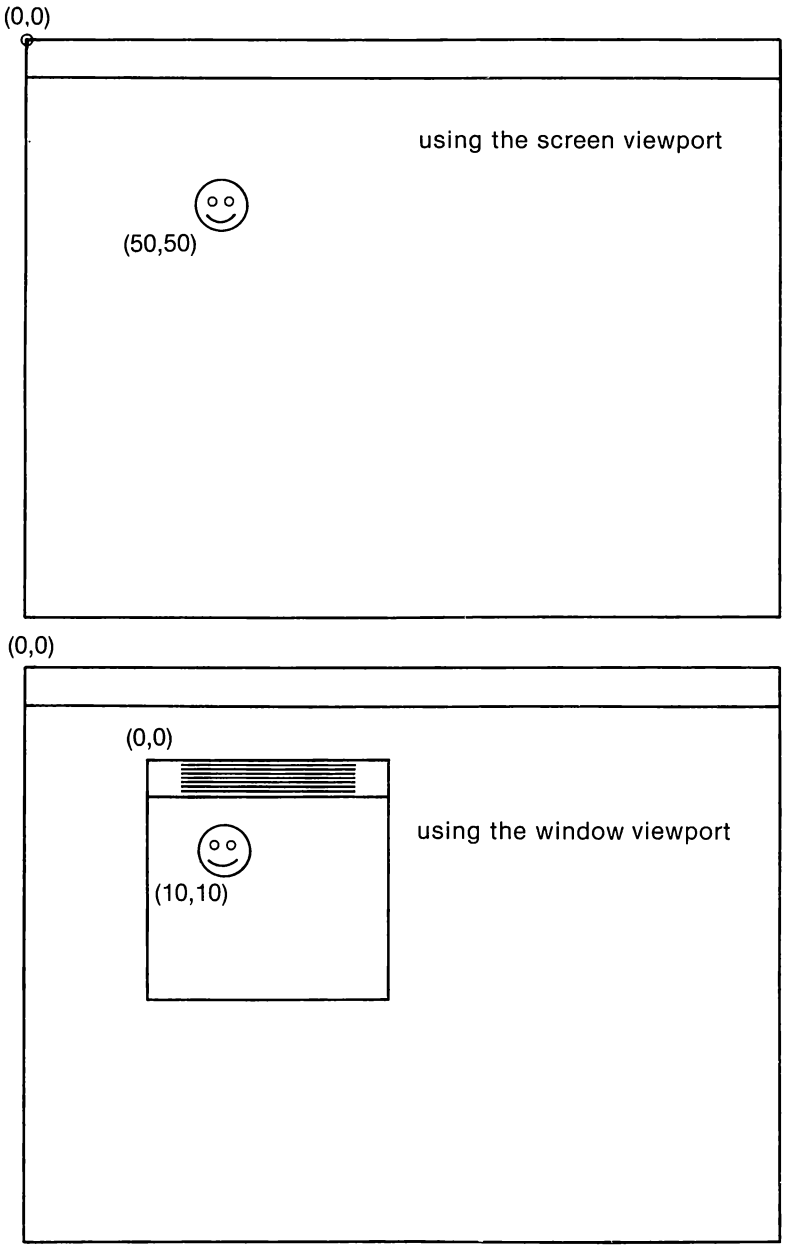
V_port is a pointer to the ViewPort of the display area or to 0 to indicate the current one. This function moves the sprite to the location *x,y* on the display area. These coordinates are relative to the overall coordinates of the displayed ViewPort; this can be either a window or a screen. Figure 6-7 illustrates this relationship. Again, even if you specify a location in relation to a window, the sprite is still an independent hardware object, not really a part of that window.

Listing 6-2 produces a multicolored sprite and causes it to move back and forth diagonally on the display screen. After calling *GetSprite()* to allocate the next available sprite, we check to make sure that the function was successful; if it was not, we exit. Next we initialize the SimpleSprite structure, *imp*. Here the critical value is setting *imp.height* to 9 to make it compatible with the data in the *imp_data* array. The *switch* statement is set up to discover which sprite was assigned to the *s_id* variable. This variable sets the variable *k* to the corresponding color register value.

Listing 6-2. Allocating and playing with a hardware sprite.

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/sprite.h>

struct Screen *Scrn;
struct Window wind;
struct SimpleSprite imp;

UWORD imp_data[]= {
   0,0,
```

Figure 6-7. The position of a sprite relative to a ViewPort



Listing 6-2. (cont.)

```
   0x0fc3,0x0000,
   0x3ff3,0x0000,
   0x30c3,0x0000,
   0x0000,0x3c03,
   0x0000,0x3fc3,
   0x0000,0x03c3,
   0xc033,0xc033,
   0xffc0,0xffc0,
   0x3f03,0x3f03,
   0,0 };


main()
{
 SHORT x,y,w,h,d,s_id,k,xmove,ymove,n,i;
 USHORT mode;
 ULONG flags;
 UBYTE *name,c0,c1;
 VOID delay_func(),OpenALL();

  OpenALL(); /* Error checking could be added here */

 /*  ======Open a hi-res custom screen==== */

  y=0;
  w=640;
  h=200;
  d=3;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,NULL);

  ShowTitle(Scrn,FALSE);

 /* ===Open a backdrop window=== */

  name=NULL;
  x=0;
  y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS|BACKDROP;
  c0=-1;
  c1=-1;

  wind=(struct Window *)
         make_window(x,y,w,h,name,flags,c0,c1,Scrn,NULL);

 /* ===Create and play with a simple hardware sprite=== */

  if((s_id=GetSprite(&imp,-1))==-1)
```

Listing 6-2. (cont.)

```
    exit();

  imp.x=0;
  imp.y=0;
  imp.height=9;

  switch(s_id)  {
    case 0:
    case 1: k=16;
            break;
    case 2:
    case 3: k=20;
            break;
    case 4:
    case 5: k=24;
            break;
    case 6:
    case 7: k=28;
            break;

   }


  SetRGB4(&Scrn->ViewPort,k+1,12,3,8);
  SetRGB4(&Scrn->ViewPort,k+2,13,13,13);
  SetRGB4(&Scrn->ViewPort,k+3,4,4,15);

  ChangeSprite(&Scrn->ViewPort,&imp,&imp_data);

  MoveSprite(0,&imp,30,0);

  xmove=1;
  ymove=1;

  for(n=0;n<4;n++)  {
    i=0;
    while(i++< 185)  {
      MoveSprite(0,&imp,imp.x+xmove,imp.y+ymove);
      WaitTOF();
     }
    ymove=-ymove;
    xmove=-xmove;
   }

 FreeSprite(s_id);

  /* =========Close down the window then the screen========*/


  CloseScreen(Scrn);

}

VOID delay_func(factor)
```

Listing 6-2. (cont.)

```
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Once our program has completed its initialization, we are ready to be creative with the sprite. We first set the colors of the three registers associated with our current choice; this is done by a call to:

```
SetRGB(v_port,c_reg,red,green,blue);
```

where

v_port is a pointer to the active ViewPort.

c_reg identifies the particular color register.

red, **green**, and **blue** set the values for these respective colors in that register.

The three primary color variables take on values between 0 and 15. These values represent the proportion of that particular color that will be mixed into the color to be associated with a particular register. In our example, we use the screen ViewPort.

Once we have set the colors that the sprite data will use, we execute *ChangeSprite()* to associate these colors with the data defined in *imp_data[]*. We initially move the sprite to location 30,0 by a call to *MoveSprite()*, and enter a loop. The loop continues to move the sprite by an increment of one through the variables *xmove* and *ymove*. By changing the sign of *ymove* on every loop, we cause the sprite to move back and forth. The heart of this inner loop is the *MoveSprite()* function call, but we also include a *WaitTOF()* command. It suspends the move until the next draw cycle (actually the video blanking period). This delay tends to make a smoother appearing program. The *FreeSprite()* function takes the sprite identifier as a parameter and deallocates the memory assigned to it. It is always necessary, when using the Amiga, to relinguish resources no longer needed.

Listing 6-3. Allocating and playing with improved hardware sprites.

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/sprite.h>
```

Listing 6-3. (cont.)

```
struct Screen *Scrn;
struct Window wind;
struct SimpleSprite imp;

UWORD imp_data[]= {
   0,0,
   0x0180,0x0000,
   0x03c0,0x0000,
   0x07e0,0x0000,
   0x0e70,0x0000,
   0x1c38,0x0000,
   0x381c,0x0000,
   0x718e,0x0000,
   0xc3c3,0x0000,
   0xc3c3,0x0000,
   0x718e,0x0000,
   0x381c,0x0000,
   0x1c38,0x0000,
   0x0e70,0x0000,
   0x07e0,0x0000,
   0x03c0,0x0000,
   0x0180,0x0000,
   0,0 };


main()
{
 SHORT s_id,x,y,w,h,d,xmove,ymove,n,i;
 USHORT mode;
 ULONG flags;
 UBYTE *name,c0,c1;
 VOID delay_func(),OpenALL();

  OpenALL();

 /*  ======Open a hi-res custom screen==== */

  y=0;
  w=640;
  h=200;
  d=3;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,NULL);

  ShowTitle(Scrn,FALSE);

 /* ===Open a backdrop window=== */

  name=NULL;
  x=0;
```

Listing 6-3. (cont.)

```
  y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS|BACKDROP;
  c0=-1;
  c1=-1;

  wind=(struct Window *)
         make_window(x,y,w,h,name,flags,c0,c1,Scrn,NULL);

 /* ===Create and play with a simple hardware sprite=== */

  init_sprite(&imp,&s_id);

  ChangeSprite(&Scrn->ViewPort,&imp,&imp_data);

  MoveSprite(0,&imp,30,0);

  xmove=1;
  ymove=1;

  for(n=0;n<4;n++)  {
    i=0;
    while(i++< 185)  {
      MoveSprite(0,&imp,imp.x+xmove,imp.y+ymove);
      WaitTOF();
     }
    ymove=-ymove;

   }

 FreeSprite(s_id);

  /* =========Close down the window then the screen========*/


  CloseScreen(Scrn);

}

init_sprite(imp,s_id)
struct SimpleSprite *imp;
SHORT *s_id;
{
  SHORT k;

  if((*s_id=GetSprite(&imp,-1))==-1)
    exit();

  imp->x=0;
  imp->y=0;
  imp->height=16;

  switch(*s_id)  {
```

Listing 6-3. (cont.)

```
    case 0:
    case 1: k=16;
            break;
    case 2:
    case 3: k=20;
            break;
    case 4:
    case 5: k=24;
            break;
    case 6:
    case 7: k=28;
            break;
   }

  SetRGB4(&Scrn->ViewPort,k+1,12,3,8);
  SetRGB4(&Scrn->ViewPort,k+2,13,13,13);
  SetRGB4(&Scrn->ViewPort,k+3,4,4,15);

}



VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

The code in Listing 6-3 produces a display similar to the first example. The program is improved in two ways:

1. All initialization has been gathered together in a single function, *init_sprite()*.
2. The sprite image has been redesigned to a more pleasant form and increased in size to 16 by 16.

The function definition makes this example a more modular program in comparison to Listing 6-2.

In Listing 6-4, we allocate and manipulate two separate sprites. Notice that we use the same image data to define each one, but we initialize them independently and have two sets of commands for each. The program moves the sprite around on the display screen. There must be a separate call to *FreeSprite()* for each sprite defined.

Listing 6-4. Allocating and playing with two hardware sprites.

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/sprite.h>

struct Screen *Scrn;
struct Window wind;
struct SimpleSprite imp0,imp1;

UWORD imp_data[]= {
   0,0,
   0x0180,0x0000,
   0x03c0,0x0000,
   0x07e0,0x0000,
   0x0e70,0x0000,
   0x1c38,0x0000,
   0x381c,0x0000,
   0x718e,0x0000,
   0xc3c3,0x0000,
   0xc3c3,0x0000,
   0x718e,0x0000,
   0x381c,0x0000,
   0x1c38,0x0000,
   0x0e70,0x0000,
   0x07e0,0x0000,
   0x03c0,0x0000,
   0x0180,0x0000,
   0,0 };


main()
{
 SHORT s_id0,s_id1,x,y,w,h,d,xmove0,ymove0,xmove1,ymove1,n,i;
 USHORT mode;
 ULONG flags;
 UBYTE *name,c0,c1;
 VOID delay_func(),OpenALL();

  OpenALL();

 /*  ======Open a hi-res custom screen==== */

  y=0;
  w=640;
  h=200;
  d=3;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,NULL);

  ShowTitle(Scrn,FALSE);
```

Listing 6-4. (cont.)

```
/* ===Open a backdrop window=== */

 name=NULL;
 x=0;
 y=0;
 w=640;
 h=200;
 flags=ACTIVATE|SMART_REFRESH|BORDERLESS|BACKDROP;
 c0=-1;
 c1=-1;

 wind=(struct Window *)
        make_window(x,y,w,h,name,flags,c0,c1,Scrn,NULL);

/* ===Create and play with a simple hardware sprite=== */

 init_sprite(&imp0,&s_id0);

 ChangeSprite(&Scrn->ViewPort,&imp0,&imp_data);

 MoveSprite(0,&imp0,30,0);

 init_sprite(&imp1,&s_id1);

 ChangeSprite(&Scrn->ViewPort,&imp1,&imp_data);

 MoveSprite(0,&imp1,35,10);

 xmove0=1;
 ymove0=1;
 xmove1=1;
 xmove1=1;

 for(n=0;n<4;n++)  {
   i=0;
   while(i++< 185)  {
     MoveSprite(0,&imp0,imp0.x+xmove0,imp0.y+ymove0);
     WaitTOF();
     MoveSprite(0,&imp1,imp1.x+xmove1,imp1.y+ymove1);
     WaitTOF();
    }
   ymove0=(-ymove0);
   ymove1=(-ymove1);

  }

FreeSprite(s_id0);
FreeSprite(s_id1);

 /* =========Close down the window then the screen========*/


 CloseScreen(Scrn);
```

Listing 6-4. (cont.)

```
}

init_sprite(imp,s_id)
struct SimpleSprite *imp;
SHORT *s_id;
{
  SHORT k;

  if((*s_id=GetSprite(&imp,-1))==-1)
    exit();

  imp->x=0;
  imp->y=0;
  imp->height=16;

  switch(*s_id)  {
    case 0:
    case 1: k=16;
            break;
    case 2:
    case 3: k=20;
            break;
    case 4:
    case 5: k=24;
            break;
    case 6:
    case 7: k=28;
            break;
  }


  SetRGB4(&Scrn->ViewPort,k+1,12,3,8);
  SetRGB4(&Scrn->ViewPort,k+2,13,13,13);
  SetRGB4(&Scrn->ViewPort,k+3,4,4,15);

}




VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Up until now the only thing you have done with sprites is to move them around the screen. You are not restricted to this activity. By creating a loop, you can continuously change any of the parameters of the object. In Listing 6-5, we not only move a sprite, but we periodically change its shape. Notice that we have two independent image data arrays. Each array defines a different shape for the sprite. To make a shape change, all we need to do is call *ChangeSprite()* and pass it the new image data array. Our example makes such a shape change controlled by the outer *for* loop. Each time this loop is incremented, a call to *ChangeSprite()* switches the sprite from its current shape to that defined by the other image data array. On even-numbered loops, we use *imp_data1*, and on odd-numbered loops, *imp_data0*. The inner loop merely moves the sprite around the display.

Listing 6-5. Changing the shape of a hardware sprite.

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/sprite.h>

struct Screen *Scrn;
struct Window wind;
struct SimpleSprite imp0,imp1;

UWORD imp_data0[]= {
   0,0,
   0x07e0,0x0000,
   0x0810,0x0000,
   0x1008,0x0000,
   0x2004,0x0000,
   0x4c32,0x0000,
   0x9e79,0x0000,
   0x8c31,0x0000,
   0x8001,0x0000,
   0x8001,0x0000,
   0x8001,0x0000,
   0x9009,0x0000,
   0x4812,0x0000,
   0x27e4,0x0000,
   0x1008,0x0000,
   0x0810,0x0000,
   0x07e0,0x0000,
   0,0 },
   imp_data1[]={
   0,0,
   0x07e0,0x0000,
   0x0810,0x0000,
   0x1008,0x0000,
   0x2004,0x0000,
   0x4c32,0x0000,
   0x9e79,0x0000,
   0x8c31,0x0000,
   0x8001,0x0000,
   0x8001,0x0000,
```

Listing 6-5. (cont.)

```
    0x87e1,0x0000,
    0x8811,0x0000,
    0x500a,0x0000,
    0x2004,0x0000,
    0x1008,0x0000,
    0x0810,0x0000,
    0x07e0,0x0000,
    0,0};


main()
{
 SHORT s_id,x,y,w,h,d,xmove0,ymove0,n,i;
 USHORT mode;
 ULONG flags;
 UBYTE *name,c0,c1;
 VOID delay_func(),OpenALL();

  OpenALL();

 /*  ======Open a hi-res custom screen==== */

  y=0;
  w=640;
  h=200;
  d=3;
  c0=0x00;
  c1=0x01;
  mode=HIRES;

  Scrn=(struct Screen *)
          make_screen(y,w,h,d,c0,c1,mode,NULL);

  ShowTitle(Scrn,FALSE);

 /* ===Open a backdrop window=== */

  name=NULL;
  x=0;
  y=0;
  w=640;
  h=200;
  flags=ACTIVATE|SMART_REFRESH|BORDERLESS|BACKDROP;
  c0=-1;
  c1=-1;

  wind=(struct Window *)
         make_window(x,y,w,h,name,flags,c0,c1,Scrn,NULL);

 /* ===Create and play with a simple hardware sprite=== */

  init_sprite(&imp0,&s_id,0,0,0,0);

  ChangeSprite(0,&imp0,&imp_data0);
```

Listing 6-5. (cont.)

```
  MoveSprite(0,&imp1,35,10);

  xmove0=1;
  ymove0=1;

  for(n=0;n<4;n++)  {
    i=0;
    while(i++< 185)  {
      MoveSprite(0,&imp0,imp0.x+xmove0,imp0.y+ymove0);
      WaitTOF();
     }
    if((n%2)==0)
      ChangeSprite(0,&imp0,&imp_data1);
    else
      ChangeSprite(0,&imp0,&imp_data0);
    ymove0=(-ymove0);

   }

 FreeSprite(s_id);

  /* =========Close down the window then the screen========*/


  CloseScreen(Scrn);

}

init_sprite(imp,s_id,s_num,r,g,b)
struct SimpleSprite *imp;
SHORT *s_id,s_num;
USHORT r,b,g;
{
  SHORT k;

  if((*s_id=GetSprite(&imp,s_num))==-1)
    exit();

  imp->x=0;
  imp->y=0;
  imp->height=16;

  switch(*s_id)  {
    case 0:
    case 1: k=16;
            break;
    case 2:
    case 3: k=20;
            break;
    case 4:
    case 5: k=24;
            break;
    case 6:
```

Listing 6-5. (cont.)

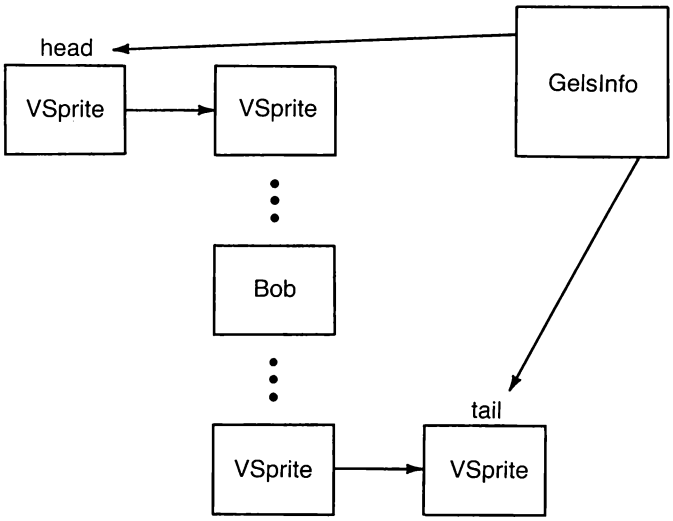
```
    case 7: k=28;
            break;
   }


  SetRGB4(&Scrn->ViewPort,k+1,r,g,b);
  SetRGB4(&Scrn->ViewPort,k+2,r,g,b);
  SetRGB4(&Scrn->ViewPort,k+3,r,g,b);

}




VOID delay_func(factor)
int factor;
/* This function will cause a specified delay */
{
 int loop;

 for(loop=0;loop<factor*1000;loop++)
   ;

 return;
}
```

Animating GELs Objects

The Amiga offers more than the eight hardware sprites we investigated. In fact, a complete range of animation objects is available to the user as part of the operating system. Of course, these can be combined into ever more complex forms through the software support found in the GELs (Graphic Elements) subsystem. Here we will discuss two basic units within this subsystem: virtual sprites (VSprites) and blitter objects (Bobs).

Before we investigate the basic building blocks of this animation system, we need to investigate the system itself. It represents a unique and straightforward way to deal with a very complex task. Each individual object that is to be animated is contained in a single linked list associated with a structure variable of type struct GelsInfo—this in turn is connected to the RastPort of the display. Furthermore this linked list is kept sorted according to the screen position of each item. All animated objects can be displayed with one system call. To add an object, it need only be inserted into this list. Removing it from the list will also remove it from the display. Figure 6-8 illustrates schematically the form of the GELs list. Note that the figure's head and tail are marked by two non-operational VSprites.

Figure 6-8. The GELs animation list



Virtual Sprites

The most basic software animation object is the virtual sprite. It uses the same basic definition of the hardware sprite but enhances it in significant ways. Although the size and shape of virtual sprites are the same as their hardware cousins (16 pixels wide, any number of lines long), there are only minor restrictions on the number of virtual sprites that can be defined. More than eight can appear on the display at a time. Furthermore, each virtual sprite can carry its own color set. The GELs system maps each virtual sprite definition onto an available hardware sprite. In fact, a particular VSprite may use the services of many different hardware sprites during a program run. Each time a new implementation is executed, the colors associated with the VSprite are pushed into that hardware sprite's color registers.

The primary limitation placed on virtual sprites by the system is directly related to their implementation by hardware sprites. Occasionally, there may not be enough of the former available to allow all the defined VSprites to be displayed. But even this restriction is not as severe as may be first perceived. The problem occurs acutely only when an attempt is made to display too many VSprites on a single line—four or more. The GELs system can handle a large number of VSprites spread over the screen.

The virtual sprite is defined through the declaration of a variable of type struct VSprite. The definition of this type is found in the header file *graphics/gels.h*. For a simple VSprite, the interesting members of this structure are:

X, Y—which represent the current position of the object;

Flags—this must be set to indicate the status of the object;

Height, Width, Depth—which define these values for the virtual sprite;

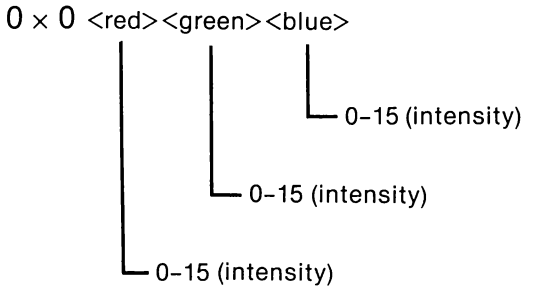
SprColors—which contains a pointer to the color information;

ImageData—which defines the shape of the sprite.

These values must be initialized by the program before the VSprite is put onto the GELs list. Since this object is restricted to a width of sixteen pixels, the Width member is always 1. Height is specified as the number of lines that the sprite object will occupy. As with hardware sprites, the maximum height can be the full size of the display. The Depth is the number of bit planes the image occupies. For a virtual sprite this parameter is always two.

The SprColors member must be set to point to an array of sixteen bit integers. These integers represent the three colors available to the virtual sprite. Each integer contains an intensity value—0 to 15—for each of the basic colors. This format is illustrated in Figure 6-9.

Figure 6-9. SprColors format



The shape of the VSprite is also defined by an array of sixteen-bit words. The bit positions in these words define which of the possible colors will be used to draw a particular pixel in the image. Since a VSprite always has a depth of 2, it takes two words to define each line of the object. These two lines are matched bit by bit. A particular color register is then associated with a specific pixel. This mechanism is illustrated in Figure 6-10. For a VSprite pixel, there are four possible combinations:

00 this defines a transparent pixel—one that does not appear;

01 this points to color register one;

10 this points to register two;

11 and this to register three.

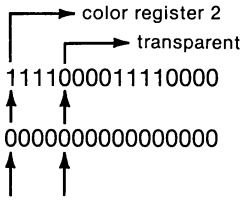
It should be noted that these numbers do not refer to an absolute color register but only those associated with the hardware sprite that will implement them. The particular values for each of these references was set by the SprColor field in the structure.

Once a VSprite variable has been declared and initialized, it must be added to the GEL system's linked list; this is done through the system call

Figure 6-10. Format for a VSprite image

```
VWORD data[ ]= { 0X0000, 0X1111,
                 0X1011, 0X0000,
                 0X0000, 0X0101,
                 0X1101, 0X1111,
```

Each line of the image is defined by two words from the array:




```
AddVSprite(v,r)
```

where *v* is a pointer to the VSprite variable that we've just created and *r* is the address of the RastPort of the display object with which the GelsInfo structure is associated. This adds the new VSprite to the list but doesn't prepare it for display. A call to this function must be included for each VSprite that is to be displayed, but the call must be done only once for each of VSprite. A complementary system call

```
RemVSprite(v)
```

will remove a particular virtual sprite from the list. As with AddVSprite( ), *v* is a pointer to the particular VSprite variable to be removed.

Displaying a GELs List

So far we have been concentrating on defining our GELs system objects and adding them to the display list. However, merely adding them to the list is not sufficient to cause them to appear on the monitor screen. There are several steps that must be performed before we can see our handiwork dancing on the display. The goal of these steps is to prroduce a set of instructions for the Amiga's custom hardware. The GELs system reduces this complex task to a series of system calls.

The first task is to sort the GELs list. The display hardware paints the monitor screen from left to right and from top to bottom. It's necessary that the objects on the GELs list be arranged in this order—as a particular part of the display is drawn, reference to the list will be made to see what else must be put in the display. This sorting is accomplished by

```
SortGList(r)
```

where *r* points to the display's RastPort. This routine uses the X and Y members to make its arrangements.

Once the list is sorted a call to

```
DrawGList(r,vp)
```

will produce the instructions and declarations necessary to render the GEL object. Here, *r* is a pointer to the RastPort of the display and *vp* is the address of the screen's ViewPort structure. Even calling this function will not actually display the objects on the GEL list. It is necessary to add the new instructions to the display program. From an Intuition screen this is accomplished by a call to

```
MakeScreen(s)
```

where *s* is a pointer to the current screen structure. This call is followed by one to

```
RethinkDisplay()
```

which will create a new screen environment. At this point the GEL objects will appear on the display.

It must be emphasized that this sequence of four system calls

```
SortGList(r)
DrawGList(r,vp)
MakeScreen(s)
RethinkDisplay()
```

must be performed each time anything about the GEL element is changed. Just changing the position of the object, requires a complete reconstruction of the display environment. In a program, these four functions will be called many times.

Programming with VSprites

The sequence of steps necessary to create and manipulate a VSprite is complicated. It is easier to understand the process within the context of programming examples. In the following examples, we will explore some simple uses of the GELs system as it relates to VSprites.

Listing 6-6. A simple VSprite program.

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/rastport.h>
#include <graphics/sprite.h>
#include <graphics/gfxmacros.h>
#include <graphics/gels.h>
#include <graphics/view.h>
#include <exec/memory.h>

#define Y_BT_BORDER 183     /* set some constants to control the VSprite */
#define Y_TP_BORDER 1       /* movement--quite arbitrary */
#define X_RT_BORDER 605
```

Listing 6-6. (cont.)

```
#define X_LF_BORDER 1

struct Screen *Scrn;
struct Window *wind;
struct VSprite vimp,vhead,vtail;
struct GelsInfo ginfo;

USHORT colors[]={0x0e30,0xffff,0x0b40};   /* set the VSprite color range */

UWORD vimp_data[]= {          /* the image data that defines the VSprite */
   0x07e0,0x07e0,
   0x0810,0x0810,
   0x1008,0x1008,
   0x2004,0x2004,
   0x4c32,0x4c32,
   0x9e79,0x9e79,
   0x8c31,0x8c31,
   0x8001,0x8001,
   0x8001,0x8001,
   0x8001,0x8001,
   0x9009,0x9009,
   0x4812,0x4812,
   0x27e4,0x27e4,
   0x1008,0x1008,
   0x0810,0x0810,
   0x07e0,0x07e0};

main()
{
 SHORT x,y,w,h,d,i;
 USHORT mode;
 ULONG flags;
 UBYTE *name,c0,c1;
 VOID delay_func(),OpenAll();
 int xin=1,yin=1;
  OpenAll();

 y=0;                              /* set up a Hi Res Custom Screen */
 w=640;
 h=200;
 d=3;
 c0=0x00;
 c1=0x01;
 mode=HIRES;
Scrn=(struct Screen *)
        make_screen(y,w,h,d,c0,c1,mode,NULL);
ShowTitle(Scrn,FALSE);

name=NULL;                  /* set up a Window to serve as a backdrop */
x=0;
y=0;
w=640;
h=200;
flags=ACTIVATE|SMART_REFRESH;
```

Listing 6-6. (cont.)

```
c0=-1;
c1=-1;

wind=(struct Window *)
       make_window(x,y,w,h,name,flags,c0,c1,Scrn,NULL);

/* initialize the GelsInfo structure */

  ginfo.nextLine=(WORD *)AllocMem(sizeof(WORD)*8,MEMF_CHIP|MEMF_CLEAR);
  ginfo.lastColor=(WORD **)AllocMem(sizeof(LONG)*8,MEMF_CHIP|MEMF_CLEAR);
  ginfo.sprRsrvd=0xfc;

/* initialize the VSprite structure */
  vimp.Height=16;
  vimp.Width=16;
  vimp.Depth=2;
  vimp.SprColors=colors;
  vimp.ImageData=vimp_data;
  vimp.X=25;
  vimp.Y=25;
  vimp.Flags=VSPRITE;

/* set up the GelsInfo system */

  wind->RPort->GelsInfo=&ginfo;    /* attach the GelsInfo to the current */
                                   /* RastPort */
  InitGels(&vhead,&vtail,&ginfo);  /* initialize it */

  AddVSprite(&vimp,wind->RPort);   /* add the VSprite to the list */
  x=y=25;
  for(i=0;i<5000;i++) {      /* move the VSprite around */
    if(x < X_LF_BORDER) {    /* change direction at the left hand border */
     x=X_LF_BORDER+1;
     xin=1;
    }
   else if( x > X_RT_BORDER) {                  /*...and a the right one */
     x=X_RT_BORDER-1;
     xin=(-1);
    }
   else
     x+=xin;

  if(y < Y_TP_BORDER) {                          /* move down at the top */
     y=Y_TP_BORDER+1;
     yin=1;
    }
   else if(y > Y_BT_BORDER) {                   /* move up at the bottom */
     y=Y_BT_BORDER-1;
     yin=(-1);
    }
   else
     y+=yin;

   vimp.X=x;
```

Listing 6-6. (cont.)

```
    vimp.Y=y;

    SortGList(wind->RPort);                          /* sort and redisplay */
    DrawGList(wind->RPort,&(Scrn->ViewPort));        /* the VSprite        */
    MakeScreen(Scrn);
    RethinkDisplay();
    WaitTOF();
   }

 CloseWindow(wind);                                 /* close down the window */
 CloseScreen(Scrn);                                 /* and the screen */
}
```

Listing 6-6 shows a simple VSprite example. This program will cause a single virtual sprite to bounce back and forth on the screen. Besides the necessary definitions and declarations for a window and a screen, four boundary constants are defined. These constants will be used later to control the movement of the sprite. Three VSprite variables are declared: *vhead* and *vtail* to define the GELs list, and *vimp* which will create a moving sprite. A single Gelsinfo structure, *ginfo*, is also declared. The two ginfo members, *nextLine* and *lastColor*, are allocated and the *sprRsrvd* member is initialized to eliminate hardware sprites 0 and 1 (to avoid any conflict with the mouse pointer). Next the appropriate values are put into the VSprite structure, *vimp*. Note that we must set the flags member of this latter structure to the flag value VSPRITE. This same structure will be used later to define a Bob. Please note that it is necessary to distinguish these two uses. Finally, the ginfo structure is attached to the RastPort of the window, a call to *InitGels()* creates the GELs list, and the VSprite structure is added to the list.

The basic operation of the program in Listing 6-6 is to move the VSprite across the screen on pixel at a time. At each move a check is mode to see if the sprite is at a boundary: if it is, the direction of movement is changed and the program continues. Each time this movement calculation is performed, the *vimp* variable is updated and the display sequence is performed. *WaitTOF()* is a system call that will cause the program to wait until all the changes have been performed.

Listing 6-7. The VSprite support library

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/rastport.h>
#include <graphics/sprite.h>
#include <graphics/gfxmacros.h>
#include <graphics/gels.h>
#include <graphics/view.h>
#include <exec/memory.h>

/* s_display() will redraw and display the GelsInfo system. */
```

Listing 6-7. (cont.)

```
s_display(w,s,vsp)
struct Window *w;
struct Screen *s;
struct VSprite *vsp;
{
 SortGList(w->RPort);                              /* sort and redisplay */
 DrawGList(w->RPort,&(s->ViewPort));               /* the VSprite        */
 MakeScreen(s);
 RethinkDisplay();
 WaitTOF();
}

/* g_init() will initialize the GelsInfo system. */

g_init(w,vhead,vtail,ginfo)
struct Window *w;
struct VSprite *vhead,*vtail;
struct GelsInfo *ginfo;
{
 ginfo->nextLine=(WORD *)AllocMem(sizeof(WORD)*8,MEMF_CHIP|MEMF_CLEAR);
 ginfo->lastColor=(WORD **)AllocMem(sizeof(LONG)*8,MEMF_CHIP|MEMF_CLEAR);
 ginfo->sprRsrvd=0xfc;

/* set up the GelsInfo system */

 w->RPort->GelsInfo=ginfo;       /* attach the GelsInfo to the current */
                                     /* RastPort */
 InitGels(vhead,vtail,ginfo);    /* initialize it */
}
```

The initialization for the GelsInfo structure must be performed for each GELs list. Note that the basic display sequence is common to all the animation programs. The GelsInfo initialization and the basic display sequence are prime candidates for exportation to a user defined library of animation support routines. Listing 6-7 shows the contents of such a library file. The *s_display()* routine takes a pointer to a window, a screen, and a VSprite and performs the rendering sequence using these objects. *G_init()* initializes the GelsInfo structure that is passed as a parameter creating a GELs list with its other two parameters as head or tail. Putting this code in independent functions will yield modules that manipulate more than one VSprite.

Listing 6-8. A VSprite program that makes changes to the VSprite.

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/rastport.h>
#include <graphics/sprite.h>
#include <graphics/gfxmacros.h>
```

Listing 6-8. (cont.)

```
#include <graphics/gels.h>
#include <graphics/view.h>
#include <exec/memory.h>


#define Y_BT_BORDER 183     /* set some constants to control the VSprite */
#define Y_TP_BORDER 1       /* movement--quite arbitrary */
#define X_RT_BORDER 605
#define X_LF_BORDER 1

struct Screen *Scrn;
struct Window *wind;
struct VSprite vimp,vhead,vtail;
struct GelsInfo ginfo;

USHORT colors[]={0x0e30,0xffff,0x0b40};   /* set the VSprite color range */

UWORD vimp_data0[]= {         /* the image data that defines the VSprite */
            0x07e0,0x07e0,
            0x0810,0x0810,
            0x1008,0x1008,
            0x2004,0x2004,
            0x4c32,0x4c32,
            0x9e79,0x9e79,
            0x8c31,0x8c31,
            0x8001,0x8001,
            0x8001,0x8001,
            0x8001,0x8001,
            0x9009,0x9009,
            0x4812,0x4812,
            0x27e4,0x27e4,
            0x1008,0x1008,
            0x0810,0x0810,
            0x07e0,0x07e0},
    vimp_data1[]={
            0x07e0,0x07e0,
            0x0810,0x0810,
            0x1008,0x1008,
            0x2004,0x2004,
            0x4c32,0x4c32,
            0x9e79,0x9e79,
            0x8c31,0x8c31,
            0x8001,0x8001,
            0x8001,0x8001,
            0x87e1,0x87e1,
            0x8811,0x8811,
            0x500a,0x500a,
            0x2004,0x2004,
            0x1008,0x1008,
            0x0810,0x0810,
            0x07e0,0x07e0};

main()
{
```

Listing 6-8. (cont.)

```
SHORT x,y,w,h,d,i;
USHORT mode;
ULONG flags;
UBYTE *name,c0,c1;
VOID delay_func(),OpenAll();
int xin=1,yin=1;

OpenAll();

y=0;                              /* set up a Hi Res Custom Screen */
w=640;
h=200;
d=3;
c0=0x00;
c1=0x01;
mode=HIRES;

Scrn=(struct Screen *)
    make_screen(y,w,h,d,c0,c1,mode,NULL);

ShowTitle(Scrn,FALSE);

name=NULL;             /* set up a Window to serve as a backdrop */
x=0;
y=0;
w=640;
h=200;
flags=ACTIVATE|SMART_REFRESH;
c0=-1;
c1=-1;

wind=(struct Window *)
    make_window(x,y,w,h,name,flags,c0,c1,Scrn,NULL);

/* initialize the GelsInfo structure */

g_init(wind,&vhead,&vtail,&ginfo);

/* initialize the VSprite structure */

vimp.Height=16;
vimp.Width=16;
vimp.Depth=2;
vimp.SprColors=colors;
vimp.ImageData=vimp_data0;
vimp.X=25;
vimp.Y=25;
vimp.Flags=VSPRITE;

AddVSprite(&vimp,wind->RPort);       /* add the VSprite to the list */

x=y=25;

for(i=0;i<1000;i++) {    /* move the VSprite around */
```

Listing 6-8. (cont.)

```
  if(x < X_LF_BORDER) {   /* change direction at the left hand border */
   x=X_LF_BORDER+1;
   xin=1;
   vimp.ImageData=vimp_data0;
   }
  else if( x > X_RT_BORDER) {                /*...and a the right one */
   x=X_RT_BORDER-1;
   xin=(-1);
   vimp.ImageData=vimp_data1;
   }
  else
   x+=xin;

  if(y < Y_TP_BORDER) {                       /* move down at the top */
   y=Y_TP_BORDER+1;
   yin=1;
   vimp.ImageData=vimp_data0;
   }
  else if(y > Y_BT_BORDER) {                 /* move up at the bottom */
   y=Y_BT_BORDER-1;
   yin=(-1);
   vimp.ImageData=vimp_data1;
   }
  else
   y+=yin;

  vimp.X=x;
  vimp.Y=y;
  s_display(wind,Scrn,&vimp);

  }


 CloseWindow(wind);                          /* close down the window */
 CloseScreen(Scrn);                          /* and the screen */
}
```

In Listing 6-8, two changes occur to the VSprite object when it reaches a boundary; not only is its direction changed but its shape as well. This latter change is accomplished by switching the value of the ImageData member back and forth between two arrays:

vimp_data0[ ] the ubiquitous happy face

vimp_data[ ] a rarer mad face.

Any change can be made to a VSprite, including a new position, a new shape, or a new color. The change will become manifest immediately after execution of the rendering sequence. Note that in this example, the functions *g_init()* and s_display( ) are used.

One of the major reasons for using the software based VSprites is the freedom we have to create and manipulate many such objects. Listing 6-9

illustrates a program that creates and manipulates two virtual sprites. In this program, the code that calculates the new position of each virtual sprite has been moved to a function *new_move()*; this will produce a program that is more straightforward in design and easier to follow. We declare two different image arrays to create distinctive looking objects. We still have only a single GelsInfo structure and a single GELs list. The *vimp0* variable is initialized and then, since many of the values will be the same, we assign *vimp1* the values from *vimp0*. It is only necessary to change the *SprColors* member and the *ImageData* pointer. Two calls to *AddVSprite()*, one for each object, create our animation list.

Listing 6-9. Manipulating several VSprites.

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/rastport.h>
#include <graphics/sprite.h>
#include <graphics/gfxmacros.h>
#include <graphics/gels.h>
#include <graphics/view.h>
#include <exec/memory.h>

#define Y_BT_BORDER 183     /* set some constants to control the VSprite */
#define Y_TP_BORDER 1       /* movement--quite arbitrary */
#define X_RT_BORDER 605
#define X_LF_BORDER 1

struct Screen *Scrn;
struct Window *wind;
struct VSprite vimp0,vimp1,vhead,vtail;
struct GelsInfo ginfo;

USHORT colors0[]={0x0f00,0x00f0,0x000f},  /* set the VSprite color range */
       colors1[]={0x00f0,0x000f,0x0f00};

UWORD vimp_data0[]= {         /* the image data that defines the VSprite */
                        0x07e0,0x07e0,
                        0x0810,0x0810,
                        0x1008,0x1008,
                        0x2004,0x2004,
                        0x4c32,0x4c32,
                        0x9e79,0x9e79,
                        0x8c31,0x8c31,
                        0x8001,0x8001,
                        0x8001,0x8001,
                        0x8001,0x8001,
                        0x9009,0x9009,
                        0x4812,0x4812,
                        0x27e4,0x27e4,
                        0x1008,0x1008,
                        0x0810,0x0810,
                        0x07e0,0x07e0},
     vimp_data1[]={
                        0x07e0,0x07e0,
```

Listing 6-9. (cont.)

```
                        0x0810,0x0810,
                        0x1008,0x1008,
                        0x2004,0x2004,
                        0x4c32,0x4c32,
                        0x9e79,0x9e79,
                        0x8c31,0x8c31,
                        0x8001,0x8001,
                        0x8001,0x8001,
                        0x87e1,0x87e1,
                        0x8811,0x8811,
                        0x500a,0x500a,
                        0x2004,0x2004,
                        0x1008,0x1008,
                        0x0810,0x0810,
                        0x07e0,0x07e0};

main()
{
 SHORT x,y,w,h,d,i;
 USHORT mode;
 ULONG flags;
 UBYTE *name,c0,c1;
 VOID delay_func(),OpenAll();
 int x0,y0,x1,y1,xin0,yin0,xin1,yin1;

 OpenAll();

 y=0;                                    /* set up a Hi Res Custom Screen */
 w=640;
 h=200;
 d=3;
 c0=0x00;
 c1=0x01;
 mode=HIRES;

 Scrn=(struct Screen *)
        make_screen(y,w,h,d,c0,c1,mode,NULL);

 ShowTitle(Scrn,FALSE);

 name=NULL;                    /* set up a Window to serve as a backdrop */
 x=0;
 y=0;
 w=640;
 h=200;
 flags=ACTIVATE|SMART_REFRESH;
 c0=-1;
 c1=-1;

 wind=(struct Window *)
       make_window(x,y,w,h,name,flags,c0,c1,Scrn,NULL);

/* initialize the GelsInfo structure */
```

Listing 6-9. (cont.)

```
  g_init(wind,&vhead,&vtail,&ginfo);

/* initialize the VSprite structures */

  vimp0.Height=16;
  vimp0.Width=16;
  vimp0.Depth=2;
  vimp0.SprColors=colors0;
  vimp0.ImageData=vimp_data0;
  vimp0.X=25;
  vimp0.Y=25;
  vimp0.Flags=VSPRITE;

  vimp1=vimp0;                /* initialize the second VSprite structure */

  vimp1.SprColors=colors1;              /* customize the second VSprite */
  vimp1.ImageData=vimp_data1;

  AddVSprite(&vimp0,wind->RPort);       /* add the VSprites to the list */
  AddVSprite(&vimp1,wind->RPort);

  x0=y0=25;
  x1=y1=30;

  for(i=0;i<1000;i++) {      /* move the VSprite around */
    new_move(&x0,&y0,&xin0,&yin0);
    vimp0.X=x0;
    vimp0.Y=y0;
    s_display(wind,Scrn,&vimp0);

    new_move(&x1,&y1,&xin1,&yin1);
    vimp1.X=x1;
    vimp1.Y=y1;
    s_display(wind,Scrn,&vimp1);
   }

  CloseWindow(wind);                          /* close down the window */
  CloseScreen(Scrn);                          /* and the screen */
}

new_move(x,y,xin,yin)
int *x,*y,*xin,*yin;
{
    if(*x < X_LF_BORDER) {   /* change direction at the left hand border */
      *x=X_LF_BORDER+1;
      *xin=1;
     }
    else if( *x > X_RT_BORDER) {              /*...and a the right one */
      *x=X_RT_BORDER-1;
      *xin=(-1);
     }
    else
      *x+=*xin;
```

Listing 6-9. (cont.)

```
  if(*y < Y_TP_BORDER) {                          /* move down at the top */
     *y=Y_TP_BORDER+1;
     *yin=1;
    }
   else if(*y > Y_BT_BORDER) {                    /* move up at the bottom */
     *y=Y_BT_BORDER-1;
     *yin=(-1);
    }
   else
     *y+=*yin;
}
```

Bobs

The other basic unit of the GELs system is the blitter object or *Bob*. The *Bob* is not rendered through the hardware sprite system; instead, it is a part of the background display. As a Bob is moved, the display area in its path is altered with a new image. These changes are rapid enough that the movement appears smooth and steady. The big advantage of the Bob is that there is no restriction on the size or width of the object's image. It does, however, take more system resources to produce and is in fact, if not in perception, slower than the virtual sprite.

From the programmer's point of view, the big difference between VSprites and Bobs is in the way the image is drawn. Since Bobs are not restricted to a sixteen pixel width, their image is created through a series of overlapping bit planes that specify a pointer to a color register for each pixel; Figure 6-11 illustrates this arrangement. This use of bit planes is identical to the way Intuition creates images.

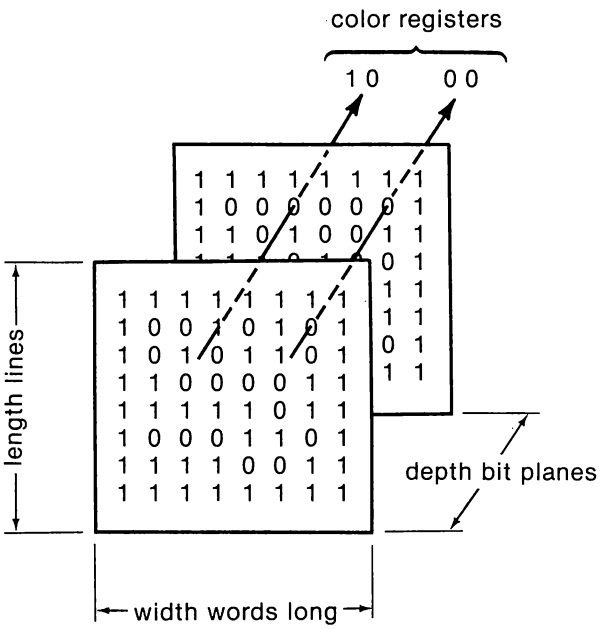
A Bob is created through the use of two associated data objects.

a variable of type struct Bob

a VSprite variable.

These two variables are linked to each other through mutually referencing members in each variable: the *VSBob* member in the VSprite and the *BobVSprite* member in the Bob variable. The VSprite variable that defines a Bob must be initialized in a slightly different way than when it is used as a virtual sprite support device. Most importantly, the *Flags* member must not be set to the VSprite flag value, also the *SprColors* member has no use and should not be initialized. *ImageData* will point at an array of sixteen bit words, but this array is arranged in a different way from the *VSprite* image. The *Depth* and *Width* members now have significance. *Depth* is set to indicate how many bit planes are used to define the Bob object—it can be anything up to and including the specified depth of the display field. As before, *Width* will contain the number of sixteen bit words necessary to specify the width of the image. Remember, this value is the number of words needed to

Figure 6-11. Bit planes for the Bob



contain all the pixels—if your Bob is, for example, 40 pixels wide, you will need to specify a Width of 3. *Depth, Height,* and *Width* define how the system will interpret your image data—each bit plane will be made up of Height rows of Width columns. Depth indicates how many of these planes are expected.

There is one additional factor that must be considered when specifying a Bob image. If the image has a depth that is shallower than the underlaying display, it is necessary to specify in which bit planes of the display the bit planes of the Bob image are to be rendered. This is illustrated in Figure 6-12. The member *PlanePick* in the VSprite structure is used to set this value. Where you place your bit plane can have an effect on the color that is used to render the Bob image. The display hardware will use all the bitplanes in the display to find the color for a given pixel. Suppose a Bob of depth 2 is drawn in the first two bit planes of a five bit plane display; this will yield a very different color register value than if it were drawn in the last two bit planes.

The GELs system that supports VSprite also controls Bobs. Bobs are added to the GELs animation list through a call to the system function.

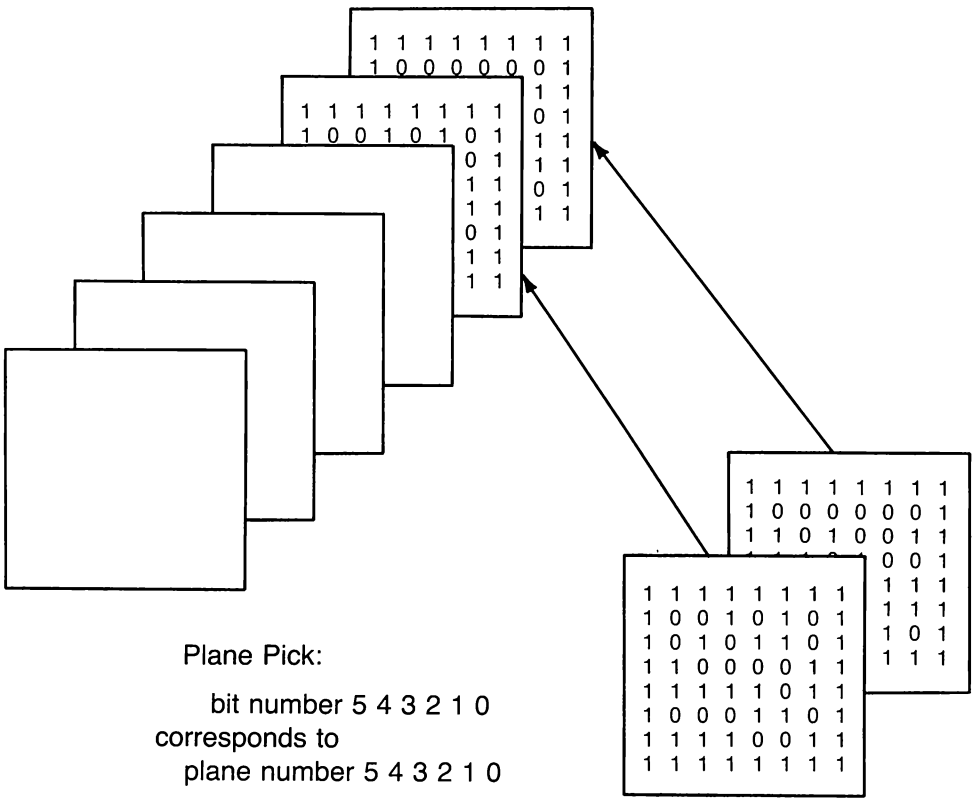
```
AddBob(b,r)
```

where *b* is a pointer to a Bob variable and *r* is the address of the display's *RastPort.* The same rendering and display sequence is used for these as for virtual sprites. A call to

```
RemIBob(b,r,vp)
```

will remove the object from the animation list. Here *b* is a pointer to the specific Bob to be removed, *r*, to the RastPort, and *vp* to ViewPort of the display environment.

Figure 6-12. PlanePick



Examples Using Bobs

As with VSprites, Bobs make more sense in context. Since they are GELs objects, we can use our support library to change and move these objects. Listing 6-10 shows a simple program using a Bob object. Within the context of a low resolution screen, we create a boxy shape of three colors and move it across the display. Whenever it comes up against a boundary, we change its direction—this is the same program we used to illustrate virtual sprites before. As the Bob moves, it drags a copy of itself along with it—effectively drawing a series of ribbons on the monitor's display.

Listing 6-10. A simple Bob program.

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/rastport.h>
#include <graphics/sprite.h>
#include <graphics/gfxmacros.h>
#include <graphics/gels.h>
#include <graphics/view.h>
#include <exec/memory.h>

#define Y_BT_BORDER 183     /* set some constants to control the VSprite */
#define Y_TP_BORDER 1       /* movement--quite arbitrary */
#define X_RT_BORDER 285
#define X_LF_BORDER 1

struct Screen *Scrn;
struct Window *wind;
struct VSprite vimp,vhead,vtail;
struct Bob bimp;
struct GelsInfo ginfo;

UWORD b_data[= {             /* the image data that defines the VSprite */

     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,

     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,

     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,

     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,

     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,
```

Listing 6-10. (cont.)

```
    0x0000,0x0000,
    0x0000,0x0000,

    0xffff,0xffff,
    0xffff,0xffff,
    0xffff,0xffff,
    0xffff,0xffff,
    0xffff,0xffff,
    0xffff,0xffff};

main()
{
 SHORT x,y,w,h,d,i;
 USHORT mode;
 ULONG flags;
 UBYTE *name,c0,c1;
 VOID delay_func(),OpenAll();
 int xin=1,yin=1;

 OpenAll();

 y=0;                                    /* set up a Custom Screen */
 w=320;
 h=200;
 d=5;
 c0=0x00;
 c1=0x01;
 mode=NULL;

 Scrn=(struct Screen *)
     make_screen(y,w,h,d,c0,c1,mode,NULL);

 ShowTitle(Scrn,FALSE);

 name=NULL;              /* set up a Window to serve as a backdrop */
 x=0;
 y=0;
 w=320;
 h=200;
 flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
 c0=-1;
 c1=-1;

 wind=(struct Window *)
     make_window(x,y,w,h,name,flags,c0,c1,Scrn,NULL);

/* initialize the GelsInfo structure */

 g_init(wind,&vhead,&vtail,&ginfo);

/* initialize the VSprite structure */

 vimp.Height=18;
 vimp.Width=2;
```

Listing 6-10. (cont.)

```
 vimp.Depth=2;
 vimp.ImageData=b_data;
 vimp.PlanePick=0x03;
 vimp.X=25;
 vimp.Y=25;

 vimp.Flags=0x0000;        /* to indicate that we're dealing with a Bob */

 vimp.VSBob=&bimp;         /* link the Bob and the VSprite structures */
 bimp.BobVSprite=&vimp;

 SetRGB4(&(Scrn->ViewPort),29,15,0,0);
 SetRGB4(&(Scrn->ViewPort),30,15,15,15);
 SetRGB4(&(Scrn->ViewPort),31,0,0,15);

 AddBob(&bimp,wind->RPort);  /* add the Bob to the list */

 x=y=25;

 for(i=0;i<1000;i++) {       /* move the Bob around */
  if(x < X_LF_BORDER) {      /* change direction at the left hand border */
   x=X_LF_BORDER+1;
   xin=1;
   }
  else if( x > X_RT_BORDER) {                  /*...and at the right one */
   x=X_RT_BORDER-1;
   xin=(-1);
   }
  else
   x+=xin;

  if(y < Y_TP_BORDER) {                         /* move down at the top */
   y=Y_TP_BORDER+1;
   yin=1;
   }
  else if(y > Y_BT_BORDER) {                    /* move up at the bottom */
   y=Y_BT_BORDER-1;
   yin=(-1);
   }
  else
   y+=yin;

  vimp.X=x;
  vimp.Y=y;

  s_display(wind,Scrn,&vimp);

  }

 CloseWindow(wind);                             /* close down the window */
 CloseScreen(Scrn);                             /* and the screen */
}
```

In this program, we not only declare our necessary three VSprite structures but also a variable of type struct Bob. Note that the image data array, *b_data* is more extensive than with the earlier VSprite example. We initialize the VSprite structure to values that represent the size and structure of the image data

Height is 18 lines

Width is 2 words

Depth is 2 bit planes

Note that we set the *PlanePick* member to draw our image in the last two bit planes of the underlying display. The Bob variable is set to point at the VSprite variable and vice versa and a call to *AddBob()* creates the animation list. Note the calls to *SetRGB4()* give the program control over the colors that will be used to display the object.

The previous example drew bold images on the display—dragging the shape of the Bob across the screen. Often, however, we want an object to move without leaving a trace of itself. This too is possible with a Bob but is a more difficult operation. We have to save the image of the display, paint the Bob in its place and when we move the Bob, replace the old image back on the display field. This is accomplished by setting the Flags member of the supporting VSprite structure to the SAVEBACK value; in order for this to work, it is necessary to specify a buffer at least as big as the Bob image to hold the displaced background display. This buffer is assigned to the *SaveBuffer* member of the Bob structure. Listing 6-11 illustrates the operation of this mechanism. It is the same program as in Listing 6-10, but we declare an extra image array, *save[]*, the same size as *b_data[]* and assign it to the appropriate member. Of course, the initialization includes the use of the SAVEBACK value.

Listing 6-11. A Bob program illustrating the SAVEBACK feature.

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/rastport.h>
#include <graphics/sprite.h>
#include <graphics/gfxmacros.h>
#include <graphics/gels.h>
#include <graphics/view.h>
#include <exec/memory.h>

#define Y_BT_BORDER 183      /* set some constants to control the VSprite
*/
#define Y_TP_BORDER 1        /* movement--quite arbitrary */
#define X_RT_BORDER 285
#define X_LF_BORDER 1

struct Screen *Scrn;
struct Window *wind;
struct VSprite vimp,vhead,vtail;
struct Bob bimp;
```

Listing 6-11. (cont.)

```
struct GelsInfo ginfo;

UWORD save[72],        /* set aside a buffer for the SAVEBACK facility */
   b_data[]= {              /* the image data that defines the VSprite */

     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,

     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,

     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,

     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,

     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,

     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff};


main()
{
 SHORT x,y,w,h,d,i;
 USHORT mode;
 ULONG flags;
 UBYTE *name,c0,c1;
```

Listing 6-11. (cont.)

```
VOID delay_func(),OpenAll();
int xin=1,yin=1;

OpenAll();

y=0;                                    /* set up a Custom Screen */
w=320;
h=200;
d=5;
c0=0x00;
c1=0x01;
mode=NULL;

Scrn=(struct Screen *)
    make_screen(y,w,h,d,c0,c1,mode,NULL);

ShowTitle(Scrn,FALSE);

name=NULL;              /* set up a Window to serve as a backdrop */
x=0;
y=0;
w=320;
h=200;
flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
c0=-1;
c1=-1;

wind=(struct Window *)
    make_window(x,y,w,h,name,flags,c0,c1,Scrn,NULL);

/* initialize the GelsInfo structure */

g_init(wind,&vhead,&vtail,&ginfo);

/* initialize the VSprite structure */

vimp.Height=18;
vimp.Width=2;
vimp.Depth=2;
vimp.ImageData=b_data;
vimp.PlanePick=0x03;
vimp.X=25;
vimp.Y=25;
vimp.Flags=SAVEBACK;              /* set the flag to redraw background */

vimp.VSBob=&bimp;           /* link the Bob and the VSprite structures */
bimp.BobVSprite=&vimp;

bimp.SaveBuffer=save;                           /* set up save buffer. */

SetRGB4(&(Scrn->ViewPort),29,15,0,0);     /* set up the color registers */
SetRGB4(&(Scrn->ViewPort),30,15,15,15);
SetRGB4(&(Scrn->ViewPort),31,0,0,15);
```

Listing 6-11. (cont.)

```
 AddBob(&bimp,wind->RPort);    /* add the Bob to the list */

 x=y=25;

 for(i=0;i<1000;i++) {       /* move the Bob around */
  if(x < X_LF_BORDER) {      /* change direction at the left hand border */
   x=X_LF_BORDER+1;
   xin=1;
   }
  else if( x > X_RT_BORDER) {                /*...and at the right one */
   x=X_RT_BORDER-1;
   xin=(-1);
   }
  else
   x+=xin;

  if(y < Y_TP_BORDER) {                       /* move down at the top */
   y=Y_TP_BORDER+1;
   yin=1;
   }
  else if(y > Y_BT_BORDER) {                  /* move up at the bottom */
   y=Y_BT_BORDER-1;
   yin=(-1);
   }
  else
   y+=yin;

  vimp.X=x;
  vimp.Y=y;
  s_display(wind,Scrn,&vimp);
  }
 CloseWindow(wind);                          /* close down the window */
 CloseScreen(Scrn);                          /* and the screen */
}
```

Finally, Listing 6-12 contains a program that will display both a VSprite and a Bob simultaneously on the display screen. Both move and change direction at each specified boundary. Since the same animation list and the same rendering commands support both kinds of objects, they can be freely mixed in a program.

Listing 6-12. An example mixing VSprites and Bobs.

```
#include <exec/types.h>
#include <intuition/intuition.h>
#include <graphics/rastport.h>
#include <graphics/sprite.h>
#include <graphics/gfxmacros.h>
#include <graphics/gels.h>
#include <graphics/view.h>
#include <exec/memory.h>
```

Listing 6-12. (cont.)

```
#define Y_BT_BORDER 183     /* set some constants to control the VSprite */
#define Y_TP_BORDER 1       /* movement--quite arbitrary */
#define X_RT_BORDER 285
#define X_LF_BORDER 1

struct Screen *Scrn;
struct Window *wind;
struct VSprite vimp0,vimp1,vhead,vtail;
struct Bob bimp;
struct GelsInfo ginfo;

USHORT colors0[]={0x0f00,0x00f0,0x000f};  /* set the VSprite color range */

UWORD vimp_data0[]= {         /* the image data that defines the VSprite */
     0x07e0,0x07e0,
     0x0810,0x0810,
     0x1008,0x1008,
     0x2004,0x2004,
     0x4c32,0x4c32,
     0x9e79,0x9e79,
     0x8c31,0x8c31,
     0x8001,0x8001,
     0x8001,0x8001,
     0x8001,0x8001,
     0x9009,0x9009,
     0x4812,0x4812,
     0x27e4,0x27e4,
     0x1008,0x1008,
     0x0810,0x0810,
     0x07e0,0x07e0},
   save[72],              /* set aside a buffer for the SAVEBACK facility */
   b_data[]= {                 /* the image data that defines the VSprite */

     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,
     0x0000,0x0000,

     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,

     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
     0xffff,0xffff,
```

Listing 6-12. (cont.)

```
    0xffff,0xffff,
    0xffff,0xffff,
    0xffff,0xffff,
    0xffff,0xffff,
    0xffff,0xffff,
    0xffff,0xffff,

    0x0000,0x0000,
    0x0000,0x0000,
    0x0000,0x0000,
    0x0000,0x0000,
    0x0000,0x0000,
    0x0000,0x0000,

    0xffff,0xffff,
    0xffff,0xffff,
    0xffff,0xffff,
    0xffff,0xffff,
    0xffff,0xffff,
    0xffff,0xffff};


main()
{
 SHORT x,y,w,h,d,i;
 USHORT mode;
 ULONG flags;
 UBYTE *name,c0,c1;
 VOID delay_func(),OpenAll();
 int x0,y0,x1,y1,xin0,yin0,xin1,yin1;

 OpenAll();

 y=0;                                    /* set up a Custom Screen */
 w=320;
 h=200;
 d=3;
 c0=0x00;
 c1=0x01;
 mode=NULL;

 Scrn=(struct Screen *)
     make_screen(y,w,h,d,c0,c1,mode,NULL);

 ShowTitle(Scrn,FALSE);

 name=NULL;              /* set up a Window to serve as a backdrop */
 x=0;
 y=0;
 w=320;
 h=200;
 flags=ACTIVATE|SMART_REFRESH|BORDERLESS;
 c0=-1;
```

Listing 6-12. (cont.)

```
 c1=-1;

 wind=(struct Window *)
     make_window(x,y,w,h,name,flags,c0,c1,Scrn,NULL);

/* initialize the GelsInfo structure */

 g_init(wind,&vhead,&vtail,&ginfo);

/* initialize the VSprite structures */

 vimp0.Height=16;
 vimp0.Width=16;
 vimp0.Depth=2;
 vimp0.SprColors=colors0;
 vimp0.ImageData=vimp_data0;
 vimp0.X=25;
 vimp0.Y=25;
 vimp0.Flags=VSPRITE;

/* initialize the second VSprite structure to support a Bob */

 vimp1.Height=18;
 vimp1.Width=2;
 vimp1.Depth=2;
 vimp1.ImageData=b_data;
 vimp1.PlanePick=0x03;
 vimp1.X=30;
 vimp1.Y=30;
 vimp1.Flags=SAVEBACK;              /* set the flag to redraw background */

 vimp1.VSBob=&bimp;           /* link the Bob and the VSprite structures */
 bimp.BobVSprite=&vimp1;

 bimp.SaveBuffer=save;                              /* set up save buffer. */

 SetRGB4(&(Scrn->ViewPort),29,15,0,0);      /* set up the color registers */
 SetRGB4(&(Scrn->ViewPort),30,15,15,15);
 SetRGB4(&(Scrn->ViewPort),31,0,0,15);

 AddBob(&bimp,wind->RPort);                    /* add the Bob to the list */

 AddVSprite(&vimp0,wind->RPort);          /* add the VSprites to the list */

 x0=y0=25;
 x1=y1=30;

 for(i=0;i<1000;i++) {       /* move the VSprite around */
  new_move(&x0,&y0,&xin0,&yin0);
  vimp0.X=x0;
  vimp0.Y=y0;
  s_display(wind,Scrn,&vimp0);

  new_move(&x1,&y1,&xin1,&yin1);
```

Listing 6-12. (cont.)

```
  vimp1.X=x1;
  vimp1.Y=y1;
  s_display(wind,Scrn,&vimp1);
  }
 CloseWindow(wind);                          /* close down the window */
 CloseScreen(Scrn);                          /* and the screen */
}

new_move(x,y,xin,yin)
int *x,*y,*xin,*yin;
{
  if(*x < X_LF_BORDER) {   /* change direction at the left hand border */
   *x=X_LF_BORDER+1;
   *xin=1;
   }
  else if( *x > X_RT_BORDER) {              /*...and at the right one */
   *x=X_RT_BORDER-1;
   *xin=(-1);
   }
  else
   *x+=*xin;

  if(*y < Y_TP_BORDER) {                    /* move down at the top */
   *y=Y_TP_BORDER+1;
   *yin=1;
   }
  else if(*y > Y_BT_BORDER) {               /* move up at the bottom */
   *y=Y_BT_BORDER-1;
   *yin=(-1);
   }
  else
   *y+=*yin;
}
```

Summary

In this short chapter, we have explored programming with the sprites, hardware controlled objects that can coexist in the display area with windows, screens, and other graphic objects. The sprites are independent of any enclosing structure and can move freely. The mouse cursor is a sprite—sprite 0, to be specific.

Controlling these useful objects is easy through a software support system offered by the Amiga. You can access the hardware parameters through the SimpleSprite structure and define its shape with an array of 16-bit words. Manipulation of sprites is facilitated by a series of system functions that allow you to initialize, change, and move them. Manipulation of VSprites and Bobs is similarly accomplished by the software environment.

We have also explored the GELs subsystem and its VSprites and Bobs building blocks.

Programming Sound

Chapter 7

Creating Sounds
Computerized Sounds
Creating Sound on the Amiga
Accessing the Audio Device
Multichannel Sound
Summary

The Amiga has the capability to produce high quality, stereophonic sound. Four independent audio channels in the hardware support a flexible and easily programmed subsystem. The audio channels are general-purpose, digital-to-analog converters rather than specialized music producing chips. This allows a wide variety of sounds, from special effects to rich and complex musical notes.

In this chapter, we will explore the important features of this subsystem. Multiple channels will be used to produce both monaural and stereophonic sound. Each example will treat, as much as possible, a single aspect of this important resource.

Creating Sounds

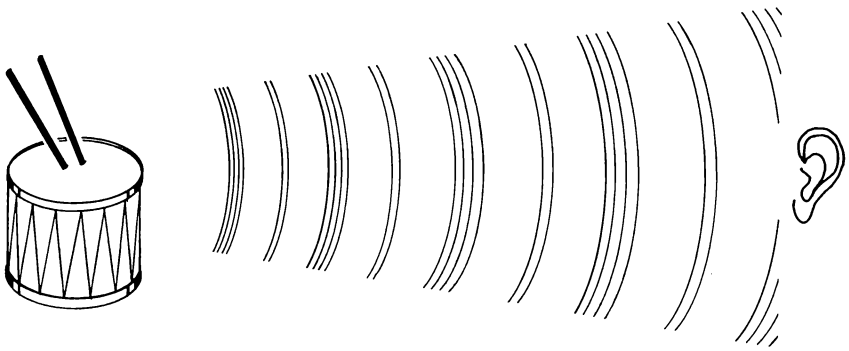
Sound is composed of compression waves in a physical medium, usually air. The source—a musical instrument, stereo speaker, etc.—produces compresssions and rarefactions of the air. These are received by our ears and translated into sounds (Figure 7-1). Two important points should be noted:

1. Sound is defined by a series of parameters.
2. The perception of sound is largely determined by a psychological component.

The scope of this chapter does not allow us to do much more than mention these important aspects of sound, but we must always keep them in mind as we start to experiment with sound generation. The psychological component of sound is especially difficult to pinpoint, even in a single occurrence. Consider the distinction between pleasant and unpleasant sounds. One person's music is another's noise. Even a particular sound takes its coloration from the circumstances: the raucous clang of the city may be pleasant after a long sojourn in the country, or unpleasant and distracting under different circumstances. More practically, certain sounds can affect their mutual perception,

producing something more than the mere sum of their parts. The Amiga's extensive sound subsystem makes this kind of experimentation easy and fun.

Figure 7-1. Sound is transmitted via a compression wave in air and then interpreted by the human ear



The physical components of sound are of more immediate interest to us. We need to understand which aspects of a sound wave vary to produce perceptible differences to our ears. Unfortunately, there are a great many parameters that affect sound, such as the temperature of the air and the acoustic properties of the space in which we are hearing the sound. However, there are three main properties which represent the key to producing any sound:

1. The frequency of the wave
2. The amplitude of the wave
3. The tone quality or timbre

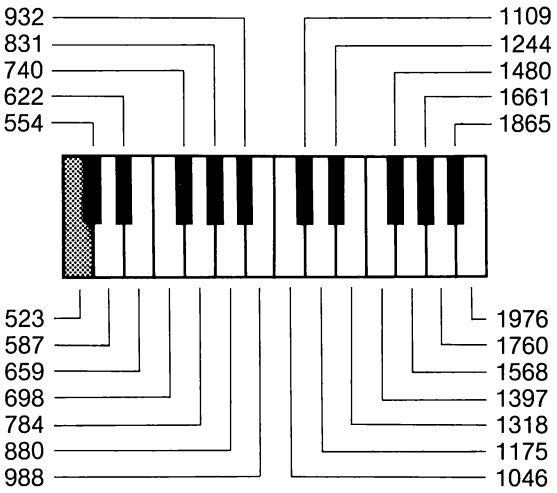
We need to establish a working definition of these qualities before proceeding much further.

The *frequency* of a sound wave is the basic parameter; waves of different frequency are perceived as different tones. Middle C on the piano, for example, is about 523 cycles per second. By varying this parameter, we can produce notes of different tone. Complex sounds—such as noise—are made up of a combination of many of such pure tones. Figure 7-2 lists frequencies for some of the most common musical tones.

The *amplitude* of a sound is another attribute whose effect is obvious; this represents the loudness of a sound. Varying this attribute makes a sound more or less faint, going to quiet on one end of the spectrum and painfully loud on the other. Less obvious is the fact that this, too, is a component in the creation of complex sounds. A mixture of different frequencies, where each has a different amplitude, sounds different than a mixture where each of the tones is at the same level of loudness.

The most difficult parameter to explain is *timbre*. This can be loosely described as the "quality of sound." The frequency dictates what tone is

Figure 7-2. Approximate frequencies of selected common musical notes



being created, but the same tone can be perceived in a variety of different ways. An example can be taken from the musical scale. An "A" note sounded on a violin and the very same note on a piano are recognizably the same note, but each also has a perceptibly different quality. You are not likely to mistake one for the other. There are a number of factors involved in defining this quality; a complete discussion is beyond the scope of this chapter. The timbre is a kind of general purpose parameter which allows us to get a handle on the complexity of a sound.

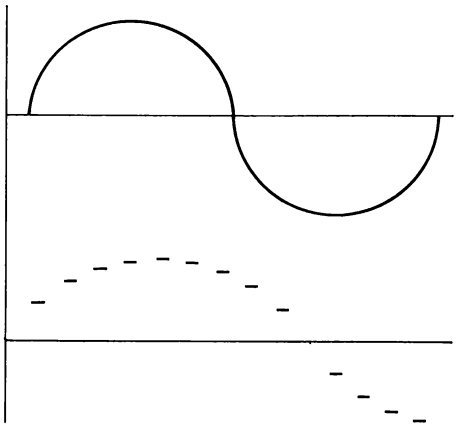
Computerized Sounds

With this general picture of the factors that go to make up a sound, we must turn our attention to the techniques for creating sounds on the Amiga. You have seen that sound is a recurring object, which may be described mathematically; this is also the way to approach sound creation from the computer side. You simulate the sound mathematically and then depend on the Amiga's circuitry to reproduce this simulation through the speakers.

The big problem in creating sound on the Amiga or any other computer is one of translation between the analog physical world and the internal digital representations used by the computer. This basic dichotomy—digital vs. analog—is illustrated in Figure 7-3. Analog quantities, such as sound, are continuous, one value merging into the next with nothing in between. Digital values, in contrast, are discrete: there is a definite transition between two adjacent values.

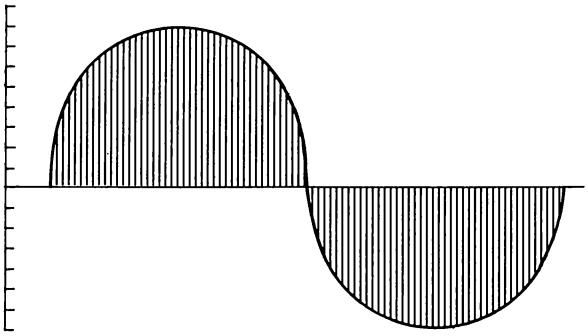
How can you represent a continuous value in terms of a discrete representation? The solution to this problem is a technique known as *sampling*

Figure 7-3. A continuous function compared to an incremental one



(Figure 7-4). A continuous quantity, such as a sound, exists over a certain time period. In the case of a sound, this time period represents one portion, or cycle, of a recurring quantity. During one of these intervals, you can note, or sample, the value present at various points in the interval. Each time you take a sample, you convert it to a number. This collection of numbers represents a discrete description of the quantity at a particular moment. A collection of numbers is easy for a computer to store and manipulate.

Figure 7-4. Sampling an analog waveform



Once this conversion from continuous values to a collection of numbers is complete, you are free to manipulate the numbers just as you would any numeric quantity in the computer. This kind of representation gives a great deal of flexibility, for not only dealing with well-behaved sounds—such as musical notes—but also for creating interesting combinations of sounds, even some that never existed in nature. This is where the power of the Amiga's sound subsystem becomes obvious.

Creating Sound on the Amiga

The specific capabilities of the Amiga to produce sound set it apart from most computers with a sound component. First of all, the Amiga produces stereo sound. Notice that on the back of the system box are both a left and a right speaker output plug; this is an unusual capability for a computer in the Amiga's price range. Each stereo channel consists of two virtual channels; these are independent sound producing circuits. It is also possible to combine these four virtual channels into a single speaker to produce a monaural sound with four components.

The fact that you are dealing with straight digital-to-analog converters and not a specialized sound chip also increases flexibility. Not only can you produce virtually any known sound within the machine's freqency range, but you can also create brand new sounds. This straight conversion also allows more accurate reproduction of musical tones. The Amiga can produce rich and pleasing notes that have none of the "computer sound" found in so many other microcomputers.

Access to the sound circuitry is through the *audio device*. This is primarily a software object that interfaces with the hardware components of the sound subsystem. Like the other driver software found on the Amiga, it runs in the multitasking environment, concurrently with any calling software. The audio device simplifies access to the hardware parameters.

Communication between a user application and the audio device is through the message system. This device has its own specialized message node that is transmitted through one of the I/O system calls; the primary ones involved here are *BeginIO()*, *WaitIO()*, and *CheckIO()*. *SendIO()* and *DoIO()* are rarely used because they interfere with some of the initialized fields in the audio device message node—they "de-initialize" the *io_Flags* field of the node.

Messages are sent:

- To initialize the sound device
- To start up a sound
- To alter the parameters of a sound
- To terminate a sound

In addition to I/O messages, the *OpenDevice()* and *CloseDevice()* system functions are used to attach or remove the audio device to a program.

The message structure type for the audio device has the following form:

```
struct IOAudio {
   struct IORequest ioa_Request;
   WORD  ioa_AllocKey;
   UBYTE *ioa_Data;
   ULONG ioa_Length;
   UWORD ioa_Period,
         ioa_Volume,
         ioa_Cycles;
   struct Message ioa_WriteMsg;
};
```

You can see the usual message structure bracketing the device-specific information fields, and you can also see that the important sound parameters each have a dedicated field in the structure. This structure definition is found in *devices/audio.h*.

Many of these fields require lengthy discussion in order to understand them fully. For now, we will briefly describe each one, so that we can begin a more complete discussion with the entire picture in mind. In the IORequest structure, the following fields will be important to our use of the audio device:

ioa_Request.io_Unit indicates which of the four possible channels is being addressed.

ioa_Request.io_Command indicates which operation the audio device is to perform.

ioa_Request.io_Flags indicates specific modifications to the commands issued to the device.

There are a number of options available for each one of these fields.

The next field, *ioa_AllocKey*, is a unique identifier returned by the device after successful allocation of one or more audio channels. This value helps tie together channels that have been allocated together. Prior allocation of the sound channels makes audio access consistent with a multitasking environment, since there is no chance that two tasks will try to simultaneously access the device. You can, however, directly call the device and have it sound immediately, without worrying about conflicts with other programs or tasks. In this latter case the *ioa_AllocKey* field is ignored.

The *ioa_Data* field serves two functions. When the audio device is initially being opened, this field holds a map of the proposed channel allocations—which are to be opened and which are not. In subsequent messages, it is a pointer to the representation of the waveform that is to be sounded. The *ioa_Length* field contains the size of the *ioa_Data* field.

The frequency of a sound is specified, not in the familiar units of cycles per second, but as its inverse, the period. There is an easy mathematical relationship between the two: the period is the reciprocal of the frequency. This value is set in *ioa_Period*. The loudness is set in *ioa_Volume*; and *ioa_Cycles* tells the device how many times to repeat the sound—how many cycles to actually play.

Sound Data Representation

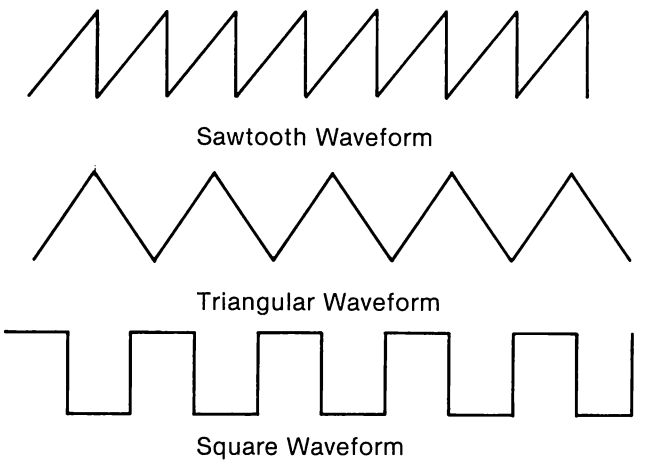
The first area to explore is the actual representation of the sound values in the machine. We noted earlier that sampling is the technique for generating a numeric representation of a continuous sound wave. A sample of a particular waveform is a series of values taken across time; that is to say, you measure the waveform at regular intervals and note its actual value. In the case of the Amiga, you measure the amplitude (loudness). This set of values can be sent to the sound subsystem, which reproduces the original sound by converting these numbers back into a series of varying voltages. These voltages, in turn,

drive the speakers. The frequency of the sound is set by specifying the sampling interval.

It is possible to actually sample sounds with the Amiga and some specialized out-board circuitry; however, because the intermediate step in the "equation" is an array of numbers, you can create your own sounds mathematically, simply by specifying these numbers. A very convenient way to do this is to fill the array using the *sin()* function. The resulting sine curve produces a pleasingly pure tone. You can just as easily initialize the values arbitrarily. There is a restriction on the range of values for this data: −127 to 127.

More realistic sounds can be generated using more complex waveforms. Figure 7-5 illustrates some other commonly used shapes, such as the sawtooth waveform. To create arbitrarily complex sounds, combinations of waveforms are used. The sample size need not be very large. Even as few as two values will yield some kind of sound. There is also no set sample size; the *ioa_Length* field tells the audio device how many values to expect.

Figure 7-5. Waveforms used to represent sound data



The frequency of a tone is set by placing a value into the period field of the IOAudio structure—*ioa_Period*. The period is the inverse of the frequency and actually specifies the time interval needed for a sample. The time unit is clock ticks, the lowest measurable interval on the computer. The mathematical relationship between the desired frequency and the period specified is calculated by the formula:

period=(microseconds per sample) ÷ 0.279.

The number of microseconds per sample is a function of the number of items in the data, and the desired frequency. For example, if you have a data set with thirty-two items and you want a frequency of 5000 Hz, then each cycle is 1/5000 second. With thirty-two samples per cycle, each sampling interval is approximately six microseconds. The period for this frequency is approximately 23. Figure 7-6 contains the period values for some musical notes. It

should be noted here that the higher the period value, the lower the frequency of the sound.

Figure 7-6. Period values for some common musical notes

C	428	214
C#	404	202
D	381	190
E	339	170
F	320	160
F#	302	151
G	285	143
G#	269	135
A	254	
A#	240	
B	226	

Accessing the Audio Device

The audio device is one of many such devices on the Amiga. As such, it is a shared resource and its usage must be allocated among the tasks and processes that need to use it. A user application must indicate to the operating system that it needs to use this device. This is accomplished by the *OpenDevice()* function. You have seen this function before in dealing with other system devices and device drivers; therefore, a lengthy discussion is not necessary. Here we will concentrate on those operations and specifications that are unique to the audio device.

The general form of a call to open the audio device takes the form:

```
OpenDevice(AUDIONAME,0L,audio_struct,0L)
```

where

AUDIONAME is a global constant designating the official name of the device.

audio_struct is an object of type struct IOAudio, set up to initialize the device.

The global value AUDIONAME is used to protect the programmer against future changes in the operating system environment. Right now, if you were to look in *audio.h*, you would find that this has the assigned value "audio.device"; but there is no guarantee against future operating system revisions. Most of our attention then will focus on the structure and how it must be set up to open the device properly.

The first thing to do with the audio structure is to attach a reply port so that you can receive return messages from the operating device. This is done by a simple call to the system function *CreatePort()*. Once you have set up the reply mechanism, only three fields need to be initialized to open the device:

ioa_Request.io_Message.mn_Node.ln_Pri to set the priority of your proposed access

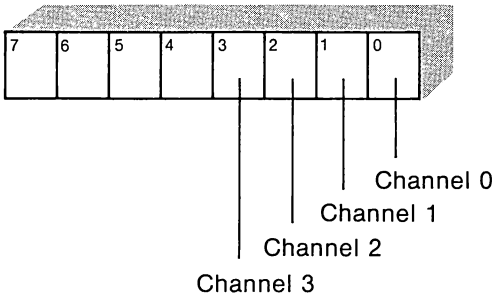
ioa_Data to indicate which of the four audio channels is to be opened

ioa_Length to show the size of the data field

The first of these fields sets the priority of the request within the multitasking environment; it should be set to a value consistent with the importance of the application. What this value should be is specific to the type of program and the circumstances of the operating environment. We use the value 10 for most of the examples in this chapter.

The *ioa_Data* field must contain a bit map indicating the channels which are to be opened by the succeeding function call. Each unit of the audio device is assigned one of the bits in this map. To indicate an open channel, its corresponding bit is set to 1. A 0 bit indicates an unused channel. Figure 7-7 indicates the relationship of bits to units.

Figure 7-7. The relationship of bits and channels in ioa_Data



The code fragment:

```
sound.ioa_Request.io_Message.mn_Node.ln_Pri=10;
sound.ioa_Data=&sunit;
sound.ioa_Length=(ULONG)sizeof(sunit);
if((OpenDevice(AUDIONAME,)oL,&sound,OL))!=NULL exit(FALSE)
```

contains the statements necessary for opening the audio device. *Sound* is a previously declared IOAudio structure and *sunit* is a UBYTE variable initial-

ized to *0x0f*. Notice that we use the *address-of* operator with sunit to assign it to *ioa_Data*. Remember, this field is doing double duty; usually it contains a pointer to the sound data. It is necessary to respect its pointer data type by sending it the address of the bit map and not merely the value. Notice, too, that *ioa_Length* is set by using the *sizeof* operator rather than by trying to figure out the correct size of the data and then initializing this field with a number. The *OpenDevice()* command expects the name of the audio device and a pointer to this newly initialized structure. The function's *flag* and *unitNumber* parameters are not used and are set to 0; these values are set by corresponding fields in the IOAudio structure. *OpenDevice* returns a NULL if the device cannot be opened.

Audio Device Commands

Like the other devices on the Amiga, the audio device supports a full range of commands. Among the most important of these are:

CMD_WRITE. This sends a message to the device to start a sound on a channel or unit.

ADCMD_FINISH. This message stops a sound.

ADCMD_PERVOL. This command alters the volume or period of an executing sound.

These commands are set in the *io_Command* field of the *ioa_Request* field within the audio structure. These are not the full range of available commands, but they are the ones that are used most frequently in sound programming.

In addition to the *ioa_Request.io_Command* field in the IOAudio structure, there is also an *io_Flags* field. Values placed in this latter field allow you to modify the basic command to fit a variety of circumstances. For example, IOF_QUICK instructs the system to give priority to your request and to bypass some of the multitasking overhead. Among the possibilities for this field beside IOF_QUICK are:

ADIOF_SYNCCYCLE. This delays execution of the command until the end of the current cycle.

ADIOF_PERVOL. This loads the values for the period and the volume set in the IOAudio structure.

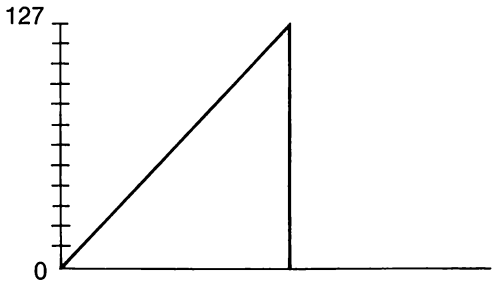
One or more of these flags is used with each specific command message.

In the simplest case, a single channel is accessed to play a sound for a set period of time. This situation is illustrated in Listing 7-1. Notice that we have incorporated our earlier fragment of code that opened the audio device, and have added the necessary declarations. A simple "for" loop creates our waveform, a sawtooth (Figure 7-8); this information is stored in the array *sound_data[]*.

Listing 7-1. The simplest use of the audio device. The cycle field is set to specify the number of cycles.

```
#include <exec/types.h>
#include <exec/memory.h>
#include <hardware/custom.h>
#include <hardware/dmabits.h>
#include <libraries/dos.h>
#include <devices/audio.h>

extern struct MsgPort *CreatePort();
struct IOAudio sound;

UBYTE sunit=0x0f,sound_data[128];

main()
{
 UBYTE i;

 if((sound.ioa_Request.io_Message.mn_ReplyPort=CreatePort("p3",0))==NULL)
   exit(FALSE);


 sound.ioa_Request.io_Message.mn_Node.ln_Pri=10;
 sound.ioa_Data=&sunit;
 sound.ioa_Length=(ULONG)sizeof(sunit);

 if((OpenDevice(AUDIONAME,0L,&sound,0L))!=NULL)  {
  printf("Can't open Audio Device\n");
  exit(FALSE);
 }

 for(i=0;i<127;i++)
   sound_data[i]=i;
 sound_data[127]=0;


 sound.ioa_Request.io_Command=CMD_WRITE;
 sound.ioa_Request.io_Flags=ADIOF_PERVOL|IOF_QUICK;
 sound.ioa_Data=sound_data;
 sound.ioa_Cycles=100;
 sound.ioa_Length=sizeof(sound_data);
 sound.ioa_Period=508;
 sound.ioa_Volume=64;

 BeginIO(&sound);
 WaitIO(&sound);

 CloseDevice(&sound);
}
```

Figure 7-8. Sawtooth waveform used to represent sound data in Listing 7-1



The final step requires an initialization of the IOAudio structure sound and the call to the I/O subsystem. Besides setting the CMD_WRITE command, we have to set the ADIOF_PERVOL flag to ensure that our sound data gets transmitted and used by the audio device. IOF_QUICK insures that our request will be transmitted and acted on immediately. The *ioa_Data* field is given the address of the *sound_data* array, and its length is assigned to *ioa_Length*. We have set the *ioa_Period* field to 508, middle C on the piano, and *ioa_Volume* to 64, the highest setting. We have a new field displayed here, *ioa_Cycles*; this sets the number of times the sampling operation will be repeated and the sound produced. We set this value to 100, a very short time. If we set this field to 0, the sound will continue until an explicit stop command is issued.

Once we have the desired values in an IOAudio structure, we send it to the device with a call to *BeginIO()*. *WaitIO()* puts our program to sleep until the device is finished and returns our io message structure. A call to *CloseDevice* is prudent, since in a multitasking environment, a device driver may not be unloaded at the time a program is finished. In fact, it cannnot be unloaded, unless all open requests have been balanced by a corresponding *CloseDevice()* call.

Controlling the Audio Device

In our first example, we set up the audio device, specified a tone and a duration, and started the sound. A more realistic sound generating program needs to exercise more control over this device. The first measure of control is the ability to start a sound and stop it explicitly, rather than specifying a duration through the *ioa_Cycles* field. The ACDMP_FINISH command replaces the CMD_Write in the *io_Command* field to stop an executing sound. Listing 7-2 shows a simple program that implements this finish command.

The interesting design feature of this program is the creation of two IOAudio structures, *sound* and *finish*, attached to the audio device. The

Listing 7-2. Simple use of the audio device, sending an explicit finish command to stop the tone.

```
#include <exec/types.h>
#include <exec/memory.h>
#include <hardware/custom.h>
#include <hardware/dmabits.h>
#include <libraries/dos.h>
#include <devices/audio.h>
#include <lattice/stdio.h>
#include <lattice/math.h>

extern struct MsgPort *CreatePort();
struct IOAudio finish,sound;

UBYTE sound_data[32],sunit=0x0f;
main()
{

 if((sound.ioa_Request.io_Message.mn_ReplyPort=CreatePort("p3",0))==NULL)
   exit(FALSE);

 if((finish.ioa_Request.io_Message.mn_ReplyPort=CreatePort("p2",0))==NULL)
   exit(FALSE);

 sound.ioa_Request.io_Message.mn_Node.ln_Pri=10;
 sound.ioa_Data=&sunit;
 sound.ioa_Length=(ULONG)sizeof(sunit);

 if((OpenDevice(AUDIONAME,0L,&sound,0L))!=NULL)  {
  printf("Can't open Audio Device\n");
  exit(FALSE);
 }

/* ===Set up the command structures=== */

 finish=sound;

 finish.ioa_Request.io_Flags=IOF_QUICK;
 finish.ioa_Request.io_Command=ADCMD_FINISH;

/*===============Finished with the initialization======*/

 fill_data(sound_data);

 sound.ioa_Request.io_Command=CMD_WRITE;
 sound.ioa_Request.io_Flags=ADIOF_PERVOL|IOF_QUICK;
 sound.ioa_Data=sound_data;
 sound.ioa_Cycles=0;
 sound.ioa_Length=sizeof(sound_data);
 sound.ioa_Period=508;
 sound.ioa_Volume=10;

 BeginIO(&sound);
```

Listing 7-2. (cont.)

```
 delay(100000);

 BeginIO(&finish);
 WaitIO(&sound);

 CloseDevice(&sound);
}

fill_data(sound)
UBYTE *sound;
{
 double x;

 for(x=-(PI/2);x<=PI/2;x+=.1)
   *sound=(UBYTE)floor(100*sin(x));
}

delay(x)
long x;
{
 long i;
 for(i=0;i<x;i++)
   ;
}
```

sound structure is used to initialize and start up the note. The finish structure, in contrast, is reserved for device control. We set up an audio structure and open the device. Once this has been successfully completed we copy the now initialized fields over to the remaining structure. At this point, we have two structures that are keyed to both the audio device and the same specific channel. Once this is done, we initialize first the sound structure to produce the tone and the finish structure to end it. This latter is accomplished by setting the *io_Command* field. We then call *BeginIO()*, passing it the sound structure; but instead of pausing our program and waiting for this command to run its course, after a suitable delay, we again call *BeginIO()*. This time we pass it the finish structure and then do a *WaitIO()*.

For the sake of simplicity, our delay function is primitive—just a large loop. However, this program illustrates a general form that can be used in larger and more complex applications. A sound generating program does not have to go to sleep after creating a note, but can do other things—perhaps set up the next note—while the audio device is processing its request.

This example program uses a generated sine curve to produce a more pleasing tone. The sine is easily computed and is a well-behaved mathematical object. Listings 7-3 and 7-4 are identical to our current example except in the waveform data; the first uses a square wave and the latter, a triangular one (Figure 7-9). These three programs serve to illustrate the differences introduced by using different waveform data.

Listing 7-3. Simple use of the audio device with a square wave.

```
#include <exec/types.h>
#include <exec/memory.h>
#include <hardware/custom.h>
#include <hardware/dmabits.h>
#include <libraries/dos.h>
#include <devices/audio.h>
#include <lattice/stdio.h>
#include <lattice/math.h>

extern struct MsgPort *CreatePort();
struct IOAudio finish,sound;

UBYTE sound_data[32],sunit=0x0f;
main()
{

 if((sound.ioa_Request.io_Message.mn_ReplyPort=CreatePort("p3",0))==NULL)
   exit(FALSE);

 if((finish.ioa_Request.io_Message.mn_ReplyPort=CreatePort("p2",0))==NULL)
   exit(FALSE);

 sound.ioa_Request.io_Message.mn_Node.ln_Pri=10;
 sound.ioa_Data=&sunit;
 sound.ioa_Length=(ULONG)sizeof(sunit);

 if((OpenDevice(AUDIONAME,0L,&sound,0L))!=NULL)  {
  printf("Can't open Audio Device\n");
  exit(FALSE);
 }

/* ===Set up the command structures=== */

 finish=sound;

 finish.ioa_Request.io_Flags=IOF_QUICK;
 finish.ioa_Request.io_Command=ADCMD_FINISH;

/*===============Finished with the initialization======*/

 fill_data(sound_data);

 sound.ioa_Request.io_Command=CMD_WRITE;
 sound.ioa_Request.io_Flags=ADIOF_PERVOL|IOF_QUICK;
 sound.ioa_Data=sound_data;
 sound.ioa_Cycles=0;
 sound.ioa_Length=sizeof(sound_data);
 sound.ioa_Period=508;
 sound.ioa_Volume=10;

 BeginIO(&sound);

 delay(100000);
```

Listing 7-3. (cont.)

```
 BeginIO(&finish);
 WaitIO(&sound);

 CloseDevice(&sound);
}

fill_data(sound)
UBYTE *sound;
{
 int x;

 *sound=0;
  sound++;
 for(x=1;x<31;x++)  {
   *sound=(x<16)?100:-100;
   sound++;
  }
 *sound=0;
}

delay(x)
long x;
{
 long i;
 for(i=0;i<x;i++)
   ;
}
```

Listing 7-4. Simple use of the audio device with a triangular wave.

```
#include <exec/types.h>
#include <exec/memory.h>
#include <hardware/custom.h>
#include <hardware/dmabits.h>
#include <libraries/dos.h>
#include <devices/audio.h>
#include <lattice/stdio.h>
#include <lattice/math.h>

extern struct MsgPort *CreatePort();
struct IOAudio finish,sound;

UBYTE sound_data[32],sunit=0x0f;
main()
{

 if((sound.ioa_Request.io_Message.mn_ReplyPort=CreatePort("p3",0))==NULL)
   exit(FALSE);

 if((finish.ioa_Request.io_Message.mn_ReplyPort=CreatePort("p2",0))==NULL)
```

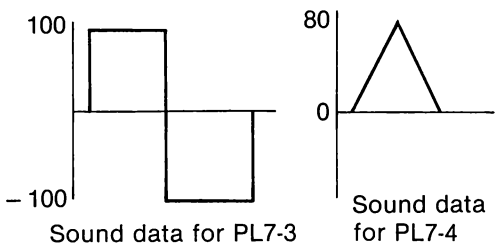
Listing 7-4. (cont.)

```
   exit(FALSE);

 sound.ioa_Request.io_Message.mn_Node.ln_Pri=10;
 sound.ioa_Data=&sunit;
 sound.ioa_Length=(ULONG)sizeof(sunit);

 if((OpenDevice(AUDIONAME,0L,&sound,0L))!=NULL)  {
  printf("Can't open Audio Device\n");
  exit(FALSE);
 }

/* ===Set up the command structures=== */

 finish=sound;

 finish.ioa_Request.io_Flags=IOF_QUICK;
 finish.ioa_Request.io_Command=ADCMD_FINISH;

/*===============Finished with the initialization======*/

 fill_data(sound_data);

 sound.ioa_Request.io_Command=CMD_WRITE;
 sound.ioa_Request.io_Flags=ADIOF_PERVOL|IOF_QUICK;
 sound.ioa_Data=sound_data;
 sound.ioa_Cycles=0;
 sound.ioa_Length=sizeof(sound_data);
 sound.ioa_Period=508;
 sound.ioa_Volume=10;

 BeginIO(&sound);

 delay(100000);

 BeginIO(&finish);
 WaitIO(&sound);

 CloseDevice(&sound);
}

fill_data(sound)
UBYTE *sound;
{
 int x;

 for(x=0;x<=100;x+=20)  {
   *sound=x;
   sound++;
  }
 for(x=80;x>=0;x-=20)  {
   *sound=x;
   sound++;
  }
 for(x=1;x<=100;x+=20)  {
```

Listing 7-4. (cont.)

```
    *sound=-x;
    sound++;
   }
  for(x=80;x>=0;x-=20)  {
    *sound=(x!=0)?-x:0;
    sound++;
   }
}

delay(x)
long x;
{
 long i;
 for(i=0;i<x;i++)
   ;
}
```

Figure 7-9. Waveforms for Listings 7-3 and 7-4



In the previous examples, we specify all of the audio channels in the IOAudio structure that was used to open the audio device. Whenever we specify a command, it is executed on the first available of the four channels. It is also desirable, however, to be able to use a single specific channel. Listing 7-5 illustrates one technique for accomplishing this goal. The bit map, *sunit*, is initialized to *0x01*; this sets the bit assigned to channel 0 in the audio device. The device is opened with only this channel active. The risk is that if that channel is in use and a process with a higher priority wants that particular channel, the call to *OpenDevice()* will fail. We will have more to say about this topic when we turn our attention to multichannel usage.

Listing 7-5. Use of a single channel of the audio device.

```
#include <exec/types.h>
#include <exec/memory.h>
#include <hardware/custom.h>
#include <hardware/dmabits.h>
#include <libraries/dos.h>
#include <devices/audio.h>
```

Listing 7-5. (cont.)

```
#include <lattice/stdio.h>
#include <lattice/math.h>

extern struct MsgPort *CreatePort();
struct IOAudio control,finish,sound;

UBYTE sound_data[32],sunit=0x01;
main()
{
 int i;
 long d;
 UWORD period=1000,loudness=64;

 if((control.ioa_Request.io_Message.mn_ReplyPort=CreatePort("p1",0))==NULL)
   exit(FALSE);

 if((finish.ioa_Request.io_Message.mn_ReplyPort=CreatePort("p2",0))==NULL)
   exit(FALSE);

 if((sound.ioa_Request.io_Message.mn_ReplyPort=CreatePort("p3",0))==NULL)
   exit(FALSE);


 control.ioa_Request.io_Message.mn_Node.ln_Pri=10;
 control.ioa_Data=&sunit;
 control.ioa_Length=(ULONG)sizeof(sunit);

 if((OpenDevice(AUDIONAME,0L,&control,0L))!=NULL)  {
  printf("Can't open Audio Device\n");
  exit(FALSE);
 }

/* ===Set up the command structures=== */

 finish=control;
 sound=control;


 finish.ioa_Request.io_Flags=IOF_QUICK;
 finish.ioa_Request.io_Command=ADCMD_FINISH;

 control.ioa_Request.io_Flags=IOF_QUICK;
 control.ioa_Request.io_Command=ADCMD_PERVOL;

/*===============Finished with the initialization======*/

 fill_data(sound_data);

 sound.ioa_Request.io_Command=CMD_WRITE;
 sound.ioa_Request.io_Flags=ADIOF_PERVOL|IOF_QUICK;
 sound.ioa_Data=sound_data;
 sound.ioa_Cycles=0;
 sound.ioa_Length=sizeof(sound_data);
 sound.ioa_Period= period;
```

Listing 7-5. (cont.)

```
 sound.ioa_Volume=loudness;

 BeginIO(&sound);

 for(i=0;i<30;i++)  {
   for(d=0;d<250;d++)
     if(d<60)
         printf("*");
   printf("\n");
   period-=5;
   loudness--;
   change_sound(&control,loudness,period);
  }

 BeginIO(&finish);
 WaitIO(&sound);

 CloseDevice(&control);
}

fill_data(sound)
UBYTE *sound;
{
 double x;

 for(x=-(PI/2);x<=PI/2;x+=.1)
   *sound=(UBYTE)floor(100*sin(x));
}

change_sound(loudness,period)
UWORD loudness,period;
{
 control.ioa_Period=period;
 control.ioa_Volume=loudness;
 BeginIO(&control);
}
```

Once a sound is executed, it is possible to change its operating parameters. Both the volume and the period can be altered. This change is accomplished through a control message to the active audio device. This message is an IOAudio structure, initialized with both the new values and the control information, and attached to the executing channel. The *io_Command* field is set to ADCMP_PERVOL to indicate the nature of the command. The *io_Flags* field should be set to IOF_QUICK, but it also may include the ADIOF_SYNCCYCLE. The use of this latter flag ensures that the changes requested will not occur until the end of a sampling cycle. Without this parameter, the changes become effective immediately.

Listing 7-6. Starting a note, then varying its period via messages sent to the audio device.

```
#include <exec/types.h>
#include <exec/memory.h>
#include <hardware/custom.h>
#include <hardware/dmabits.h>
#include <libraries/dos.h>
#include <devices/audio.h>
#include <lattice/stdio.h>
#include <lattice/math.h>

extern struct MsgPort *CreatePort();
UBYTE s_data0[32],sunit=0x0f;

main()
{
 int x,y;
 struct IOAudio control,finish,sound0;

 setup(&control,&finish);

 sound0=control;

 grab_channel(&sound0,&control,"c1");

 fill_data(s_data0);

 for(;;)  {

   printf("enter period->");
   scanf("%d",&x);
   if(x==-1)
      break;
   printf("enter volume->");
   scanf("%d",&y);

   sound_note(&sound0,(UWORD)x,(UWORD)y);

   BeginIO(&sound0);
   for(;x>=135;x-=28)  {
      delay();
      printf("new note\n");
      change_sound((UWORD)y,(UWORD)x,&control);
    }
   BeginIO(&finish);
   WaitIO(&sound0);
 }

 CloseDevice(&control);
}
setup(control,finish)
struct IOAudio *control,*finish;
{
```

Listing 7-6. (cont.)

```
if((control->ioa_Request.io_Message.mn_ReplyPort=CreatePort("p1",0))==NULL)
   exit(FALSE);

 if((finish->ioa_Request.io_Message.mn_ReplyPort=CreatePort("p2",0))==NULL)
   exit(FALSE);

 control->ioa_Request.io_Message.mn_Node.ln_Pri=10;
 control->ioa_Data=&sunit;
 control->ioa_Length=(ULONG)sizeof(sunit);

 if((OpenDevice(AUDIONAME,0L,control,0L))!=NULL)  {
  printf("Can't open Audio Device\n");
  exit(FALSE);
 }

/* ===Set up the command structures=== */

 *finish=*control;

 finish->ioa_Request.io_Flags=IOF_QUICK;
 finish->ioa_Request.io_Command=ADCMD_FINISH;

 control->ioa_Request.io_Flags=IOF_QUICK;
 control->ioa_Request.io_Command=ADCMD_PERVOL;
}

fill_data(s0)
UBYTE *s0;
{
 double x;

 for(x=-(PI/2);x<=PI/2;x+=.1)  {
   *s0=(UBYTE)floor(100*sin(x));
   s0++;
  }
}

change_sound(loudness,period,control)
UWORD loudness,period;
struct IOAudio *control;
{
 control->ioa_Period=period;
 control->ioa_Volume=loudness;
 BeginIO(control);
 WaitIO(control);
}

sound_note(chnl,period,loudness)
struct IOAudio *chnl;
UWORD period,loudness;
{
  chnl->ioa_Request.io_Command=CMD_WRITE;
  chnl->ioa_Request.io_Flags=ADIOF_PERVOL|IOF_QUICK;
```

Listing 7-6. (cont.)

```
  chnl->ioa_Data=s_data0;
  chnl->ioa_Cycles=0;
  chnl->ioa_Length=sizeof(s_data0);
  chnl->ioa_Period= period;
  chnl->ioa_Volume=loudness;
}

grab_channel(sound,control,name)
struct IOAudio *sound,*control;
char *name;
{
 if((sound->ioa_Request.io_Message.mn_ReplyPort=CreatePort(name,0))==NULL)
 *sound=*control;
}
delay()
{
 int i;
 for(i=0;i<1000;i++);
}
```

Listing 7-6 illustrates a program that will start up a sound and then vary its period in steps. Since this is a demonstration program, a message is displayed on the screen each time the period is changed. In this program, we have created three audio structures:

sound—to start up the initial note on the device

finish—to stop the note

control—to carry intermediate messages to the audio device

The latter two structures are not strictly necessary. One general control structure could serve both functions; however, having both increases the flexibility of control. At least one structure besides sound is needed; otherwise the note cannot be stopped once it is started. A *WaitIO()* on an IOAudio structure, where the *ioa_Cycle* field has been set to 0, is infinite, at least until you lose patience and reboot. When juggling multiple channels, the separate structures for control and finish become even more attractive.

The process of changing a sound's period is simple. Notice the function *change_sound()*. We simply set the new period value and call a *BeginIO()* followed by a *WaitIO()*. This function is a general purpose function; it is also used to change the volume of the sounded note. A program to change the volume over a range going down to a value of 0 is shown in Listing 7-7.

Listing 7-7. Starting a note and varying loudness via messages sent to the audio device.

```
#include <exec/types.h>
#include <exec/memory.h>
#include <hardware/custom.h>
#include <hardware/dmabits.h>
```

Listing 7-7. (cont.)

```
#include <libraries/dos.h>
#include <devices/audio.h>
#include <lattice/stdio.h>
#include <lattice/math.h>

extern struct MsgPort *CreatePort();
UBYTE s_data0[32],sunit=0x0f;

main()
{
 int x,y;
 struct IOAudio control,finish,sound0;

 setup(&control,&finish);

 sound0=control;

 grab_channel(&sound0,&control,"c1");

 fill_data(s_data0);

 for(;;)  {

   printf("enter period->");
   scanf("%d",&x);
   if(x==-1)
      break;
   printf("enter volume->");
   scanf("%d",&y);

   sound_note(&sound0,(UWORD)x,(UWORD)y);

   BeginIO(&sound0);
   for(;y>=0;y--)  {
      delay();
      printf("new loudness level\n");
      change_sound((UWORD)y,(UWORD)x,&control);
    }
   BeginIO(&finish);
   WaitIO(&sound0);
 }

 CloseDevice(&control);
}
setup(control,finish)
struct IOAudio *control,*finish;
{

if((control->ioa_Request.io_Message.mn_ReplyPort=CreatePort("p1",0))==NULL)
   exit(FALSE);

 if((finish->ioa_Request.io_Message.mn_ReplyPort=CreatePort("p2",0))==NULL)
   exit(FALSE);
```

Listing 7-7. (cont.)

```
 control->ioa_Request.io_Message.mn_Node.ln_Pri=10;
 control->ioa_Data=&sunit;
 control->ioa_Length=(ULONG)sizeof(sunit);

 if((OpenDevice(AUDIONAME,0L,control,0L))!=NULL)  {
  printf("Can't open Audio Device\n");
  exit(FALSE);
 }

/* ===Set up the command structures=== */

 *finish=*control;

 finish->ioa_Request.io_Flags=IOF_QUICK;
 finish->ioa_Request.io_Command=ADCMD_FINISH;

 control->ioa_Request.io_Flags=IOF_QUICK;
 control->ioa_Request.io_Command=ADCMD_PERVOL;
}

fill_data(s0)
UBYTE *s0;
{
 double x;

 for(x=-(PI/2);x<=PI/2;x+=.1)  {
   *s0=(UBYTE)floor(100*sin(x));
   s0++;
  }
}

change_sound(loudness,period,control)
UWORD loudness,period;
struct IOAudio *control;
{
 control->ioa_Period=period;
 control->ioa_Volume=loudness;
 BeginIO(control);
 WaitIO(control);
}

sound_note(chnl,period,loudness)
struct IOAudio *chnl;
UWORD period,loudness;
{
  chnl->ioa_Request.io_Command=CMD_WRITE;
  chnl->ioa_Request.io_Flags=ADIOF_PERVOL|IOF_QUICK;
  chnl->ioa_Data=s_data0;
  chnl->ioa_Cycles=0;
  chnl->ioa_Length=sizeof(s_data0);
  chnl->ioa_Period= period;
  chnl->ioa_Volume=loudness;
}
```

Listing 7-7. (cont.)

```
grab_channel(sound,control,name)
struct IOAudio *sound,*control;
char *name;
{
 if((sound->ioa_Request.io_Message.mn_ReplyPort=CreatePort(name,0))==NULL)
 *sound=*control;
}
delay()
{
 int i;
 for(i=0;i<1000;i++);
}
```

As might be expected, a volume of 0 shuts off the sound. Listings 7-8 and 7-9 illustrate some interesting variations on these earlier examples. In the former, we vary the volume of a sound using values in an array. This array has been filled using a *sine* function. In Listing 7-9, the period is varied in the same way. These examples serve to illustrate the kind of experimentation that is possible with the Amiga's sound subsystem.

Listing 7-8. Varying the loudness of a note. Loudness values are taken from an array of values.

```
#include <exec/types.h>
#include <exec/memory.h>
#include <hardware/custom.h>
#include <hardware/dmabits.h>
#include <libraries/dos.h>
#include <devices/audio.h>
#include <lattice/stdio.h>
#include <lattice/math.h>

extern struct MsgPort *CreatePort();
UBYTE s_data0[32],sunit=0x0f;

main()
{
 int x,j,vol[315];
 struct IOAudio control,finish,sound0;

 setup(&control,&finish);

 sound0=control;

 grab_channel(&sound0,&control,"c1");

 fill_data(s_data0);
 fill_array(vol);

 for(;;)  {
```

Listing 7-8. (cont.)

```
    printf("enter period->");
    scanf("%d",&x);
    if(x==-1)
       break;

    sound_note(&sound0,(UWORD)x,(UWORD)vol[0]);

    BeginIO(&sound0);
    for(j=1;j<315;j++)  {
       delay();
       printf("vol[%d]=%d\n",j,vol[j]);
       change_sound((UWORD)vol[j],(UWORD)x,&control);
     }
    BeginIO(&finish);
    WaitIO(&sound0);
  }

  CloseDevice(&control);
}
setup(control,finish)
struct IOAudio *control,*finish;
{

if((control->ioa_Request.io_Message.mn_ReplyPort=CreatePort("p1",0))==NULL)
    exit(FALSE);

 if((finish->ioa_Request.io_Message.mn_ReplyPort=CreatePort("p2",0))==NULL)
    exit(FALSE);

 control->ioa_Request.io_Message.mn_Node.ln_Pri=10;
 control->ioa_Data=&sunit;
 control->ioa_Length=(ULONG)sizeof(sunit);

 if((OpenDevice(AUDIONAME,0L,control,0L))!=NULL)  {
  printf("Can't open Audio Device\n");
  exit(FALSE);
 }

/* ====Set up the command structures=== */

 *finish=*control;

 finish->ioa_Request.io_Flags=IOF_QUICK;
 finish->ioa_Request.io_Command=ADCMD_FINISH;

 control->ioa_Request.io_Flags=IOF_QUICK;
 control->ioa_Request.io_Command=ADCMD_PERVOL;
}

fill_data(s0)
UBYTE *s0;
{
 double x;
```

Listing 7-8. (cont.)

```
 for(x=-(PI/2);x<=PI/2;x+=.1)  {
   *s0=(UBYTE)floor(100*sin(x));
   s0++;
  }
}

change_sound(loudness,period,control)
UWORD loudness,period;
struct IOAudio *control;
{
 control->ioa_Period=period;
 control->ioa_Volume=loudness;
 BeginIO(control);
 WaitIO(control);
}

sound_note(chnl,period,loudness)
struct IOAudio *chnl;
UWORD period,loudness;
{
  chnl->ioa_Request.io_Command=CMD_WRITE;
  chnl->ioa_Request.io_Flags=ADIOF_PERVOL|IOF_QUICK;
  chnl->ioa_Data=s_data0;
  chnl->ioa_Cycles=0;
  chnl->ioa_Length=sizeof(s_data0);
  chnl->ioa_Period= period;
  chnl->ioa_Volume=loudness;
}

grab_channel(sound,control,name)
struct IOAudio *sound,*control;
char *name;
{
 if((sound->ioa_Request.io_Message.mn_ReplyPort=CreatePort(name,0))==NULL)
 *sound=*control;
}
delay()
{
 int i;
 for(i=0;i<1000;i++);
}

fill_array(s0)
int *s0;
{
 double x;

 for(x=-PI;x<=PI;x+=.02)  {
   *s0=(int)floor(25*sin(x)+25);
   s0++;
  }
}
```

Listing 7-9. Varying the period of a note. Period values are taken from an array of values.

```
#include <exec/types.h>
#include <exec/memory.h>
#include <hardware/custom.h>
#include <hardware/dmabits.h>
#include <libraries/dos.h>
#include <devices/audio.h>
#include <lattice/stdio.h>
#include <lattice/math.h>

extern struct MsgPort *CreatePort();
UBYTE s_data0[32],sunit=0x0f;

main()
{
 int x,y,j,vol[63];
 struct IOAudio control,finish,sound0;

 setup(&control,&finish);

 sound0=control;

 grab_channel(&sound0,&control,"c1");

 fill_data(s_data0);
 fill_array(vol);

 for(;;)  {

   printf("enter period->");
   scanf("%d",&x);
   if(x==-1)
      break;
   printf("enter volume->");
   scanf("%d",&y);

   sound_note(&sound0,(UWORD)x,(UWORD)y);

   BeginIO(&sound0);
   for(j=1;j<63;j++)  {
      delay();
      printf("vol[%d]=%d\n",j,vol[j]);
      change_sound((UWORD)y,(UWORD)vol[j],&control);
    }
   BeginIO(&finish);
   WaitIO(&sound0);
 }

 CloseDevice(&control);
}
setup(control,finish)
struct IOAudio *control,*finish;
{
```

Listing 7-9. (cont.)

```
if((control->ioa_Request.io_Message.mn_ReplyPort=CreatePort("p1",0))==NULL)
   exit(FALSE);

 if((finish->ioa_Request.io_Message.mn_ReplyPort=CreatePort("p2",0))==NULL)
   exit(FALSE);

 control->ioa_Request.io_Message.mn_Node.ln_Pri=10;
 control->ioa_Data=&sunit;
 control->ioa_Length=(ULONG)sizeof(sunit);

 if((OpenDevice(AUDIONAME,0L,control,0L))!=NULL)  {
  printf("Can't open Audio Device\n");
  exit(FALSE);
 }

/* ===Set up the command Structures=== */

 *finish=*control;

 finish->ioa_Request.io_Flags=IOF_QUICK;
 finish->ioa_Request.io_Command=ADCMD_FINISH;

 control->ioa_Request.io_Flags=IOF_QUICK;
 control->ioa_Request.io_Command=ADCMD_PERVOL;
}

fill_data(s0)
UBYTE *s0;
{
 double x;

 for(x=-(PI/2);x<=PI/2;x+=.1)  {
   *s0=(UBYTE)floor(100*sin(x));
   s0++;
  }
}

change_sound(loudness,period,control)
UWORD loudness,period;
struct IOAudio *control;
{
 control->ioa_Period=period;
 control->ioa_Volume=loudness;
 BeginIO(control);
 WaitIO(control);
}

sound_note(chnl,period,loudness)
struct IOAudio *chnl;
UWORD period,loudness;
{
  chnl->ioa_Request.io_Command=CMD_WRITE;
  chnl->ioa_Request.io_Flags=ADIOF_PERVOL|IOF_QUICK;
  chnl->ioa_Data=s_data0;
```

Listing 7-9. (cont.)

```
  chnl->ioa_Cycles=0;
  chnl->ioa_Length=sizeof(s_data0);
  chnl->ioa_Period= period;
  chnl->ioa_Volume=loudness;
}

grab_channel(sound,control,name)
struct IOAudio *sound,*control;
char *name;
{
 if((sound->ioa_Request.io_Message.mn_ReplyPort=CreatePort(name,0))==NULL)
 *sound=*control;
}
delay()
{
 int i;
 for(i=0;i<1000;i++);
}

fill_array(s0)
int *s0;
{
 double x;

 for(x=-PI;x<=PI;x+=.1)  {
   *s0=(int)floor(50*sin(x)+50);
   s0++;
  }
}
```

Multichannel Sound

The Amiga has four independent sound channels attached to two output jacks. More complex sound-oriented programming involves the manipulation of more than one of these channels at a time. This added level of complexity requires careful consideration of coordination and synchronization.

When you open the audio device, you specify which of the four channels you require. These channels are specified in the bit map that is assigned to the *ioa_Data* field. Once this has been done, however, you can still send command messages to this device, that are specifically aimed at a particular channel. This information is specified in the *ioa_Request.io_Unit* field of the audio structure. By exercising this control, you can produce interesting effects, such as stereo sound.

Listing 7-10 contains a program that illustrates this kind of control. This program requires the attachment of two speakers to the two audio jacks on the Amiga. It sounds a note first on the left speaker and then moves it to the right speaker.

Listing 7-10. Playing a note first on the left channel, then on the right.

```
#include <exec/types.h>
#include <exec/memory.h>
#include <hardware/custom.h>
#include <hardware/dmabits.h>
#include <libraries/dos.h>
#include <devices/audio.h>
#include <lattice/stdio.h>
#include <lattice/math.h>

extern struct MsgPort *CreatePort();
UBYTE s_data0[32],s_data1[32],sunit=0x0f,
      mapleft=0x09,mapright=0x06;

main()
{
 int x,y,j;
 UBYTE unit0,unit1;
 struct IOAudio control,finish,sound0,sound1;

 setup(&control,&finish,&unit0,&unit1);

 sound0=control;
 sound0.ioa_Request.io_Unit=unit0;

 sound1=control;
 sound1.ioa_Request.io_Unit=unit1;


 grab_channel(&sound0,&control,"c1");
 grab_channel(&sound1,&control,"c2");

 fill_data(s_data0);
 fill_data(s_data1);

 for(;;)  {

   printf("enter period->");
   scanf("%d",&x);
   if(x==-1)
      break;
   printf("enter volume->");
   scanf("%d",&y);

   sound_note(&sound0,(UWORD)x,(UWORD)y);
   sound_note(&sound1,(UWORD)x,(UWORD)y);

   BeginIO(&sound0);
   WaitIO(&sound0);

   BeginIO(&sound1);
   WaitIO(&sound1);
}
```

Listing 7-10. (cont.)

```
 CloseDevice(&control);
}
setup(control,finish,unit0,unit1)
struct IOAudio *control,*finish;
UBYTE *unit0,*unit1;
{

if((control->ioa_Request.io_Message.mn_ReplyPort
   =CreatePort("p1",0))==NULL)exit(FALSE);

 if((finish->ioa_Request.io_Message.mn_ReplyPort
   =CreatePort("p2",0))==NULL)exit(FALSE);

 control->ioa_Request.io_Message.mn_Node.ln_Pri=10;
 control->ioa_Data=&sunit;
 control->ioa_Length=(ULONG)sizeof(sunit);

 if((OpenDevice(AUDIONAME,0L,control,0L))!=NULL)  {
  printf("Can't open Audio Device\n");
  exit(FALSE);
 }
 *unit0=((UBYTE)control->ioa_Request.io_Unit & mapleft);
 *unit1=((UBYTE)control->ioa_Request.io_Unit & mapright);

/* ===Set up the command structures=== */

 *finish=*control;

 finish->ioa_Request.io_Flags=IOF_QUICK;
 finish->ioa_Request.io_Command=ADCMD_FINISH;

 control->ioa_Request.io_Flags=IOF_QUICK;
 control->ioa_Request.io_Command=ADCMD_PERVOL;
}

fill_data(s0)
UBYTE *s0;
{
 double x;

 for(x=-(PI/2);x<=PI/2;x+=.1)  {
   *s0=(UBYTE)floor(100*sin(x));
   s0++;
  }
}

change_sound(loudness,period,control)
UWORD loudness,period;
struct IOAudio *control;
{
 control->ioa_Period=period;
 control->ioa_Volume=loudness;
 BeginIO(control);
 WaitIO(control);
```

Listing 7-10. (cont.)

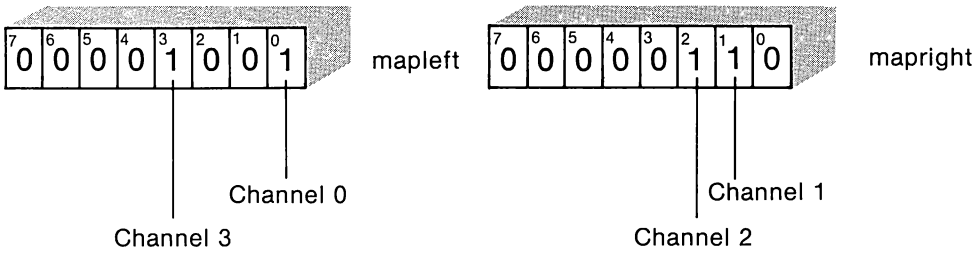
```
}

sound_note(chnl,period,loudness)
struct IOAudio *chnl;
UWORD period,loudness;
{
  chnl->ioa_Request.io_Command=CMD_WRITE;
  chnl->ioa_Request.io_Flags=ADIOF_PERVOL|IOF_QUICK;
  chnl->ioa_Data=s_data0;
  chnl->ioa_Cycles=1000;
  chnl->ioa_Length=sizeof(s_data0);
  chnl->ioa_Period= period;
  chnl->ioa_Volume=loudness;
}

grab_channel(sound,control,name)
struct IOAudio *sound,*control;
char *name;
{
 if((sound-
>ioa_Request.io_Message.mn_ReplyPort=CreatePort(name,0))==NULL)
 *sound=*control;
}
delay()
{
 int i;
 for(i=0;i<1000;i++);
}
```

In this program, we have allocated a separate audio structure for each speaker—*sound0* and *sound1*. As before, we open the device along with all four channels. Once we have done this, we need a way to get a handle on the specific channels. We do this through the bit maps *mapleft* and *mapright*. Each of these serves as a mask to block out all but those bits that refer to the channels on their respective sides of the stereo setup (Figure 7-10). The bitwise "and" operator combines each of these bits maps to the corresponding *io_Unit* field to extract the appropriate unit identification. At the end of this procedure, each audio structure contains a unit number identical to one that would result from opening the device and specifying only those channels.

Once we have properly initialized our two structures, we can begin our sound. First we call *BeginIO()* and pass it *sound0*. The program does a *WaitIO()* until this note is finished, then does a *BeginIO()* and a *WaitIO()* on sound1. To simplify this example, we set the *ioa_Cycles* field rather than creating a continuous sound and using a *finish* command.

In Listing 7-11, we have a more complex situation. Here we start a note on the left speaker, as before, then play it on both speakers simultaneously. Finally, we finish it up on the right speaker. We create the standard audio structures: control, finish, sound0, and sound1. We set the period and volume

Figure 7-10. Values for the variables mapleft and mapright



as before. We initiate the sound by doing a *BeginIO()*, using sound0, but, instead of performing a *WaitIO()* on this command, we delay for a set period and do another *BeginIO()* with sound1. After another delay, we send a finish message to stop the sound in the left speaker. Finially, after a third delay, we send a finish command to the remaining channel.

Listing 7-11. Playing a note first on the left channel, then on both, then on the right channel. The finish command is used.

```
#include <exec/types.h>
#include <exec/memory.h>
#include <hardware/custom.h>
#include <hardware/dmabits.h>
#include <libraries/dos.h>
#include <devices/audio.h>
#include <lattice/stdio.h>
#include <lattice/math.h>

extern struct MsgPort *CreatePort();
UBYTE s_data0[32],s_data1[32],sunit=0x0f,
      mapleft=0x09,mapright=0x06;

main()
{
 int x,y,j;
 UBYTE unit0,unit1;
 struct IOAudio control,finish,sound0,sound1;

 setup(&control,&finish,&unit0,&unit1);

 sound0=control;
 sound0.ioa_Request.io_Unit=unit0;

 sound1=control;
 sound1.ioa_Request.io_Unit=unit1;


 grab_channel(&sound0,&control,"c1");
 grab_channel(&sound1,&control,"c2");
```

Listing 7-11. (cont.)

```
 fill_data(s_data0);
 fill_data(s_data1);

 for(;;)  {

   printf("enter period->");
   scanf("%d",&x);
   if(x==-1)
      break;
   printf("enter volume->");
   scanf("%d",&y);

   sound_note(&sound0,(UWORD)x,(UWORD)y);
   sound_note(&sound1,(UWORD)x,(UWORD)y);

   BeginIO(&sound0);
   delay(100000);
   BeginIO(&sound1);
   delay(100000);
   finish.ioa_Request.io_Unit=unit0;
   BeginIO(&finish);
   WaitIO(&finish);
   delay(100000);
   finish.ioa_Request.io_Unit=unit1;
   BeginIO(&finish);
   WaitIO(&finish);
 }

 CloseDevice(&control);
}
setup(control,finish,unit0,unit1)
struct IOAudio *control,*finish;
UBYTE *unit0,*unit1;
{

if((control->ioa_Request.io_Message.mn_ReplyPort
   =CreatePort("p1",0))==NULL)exit(FALSE);

 if((finish->ioa_Request.io_Message.mn_ReplyPort
   =CreatePort("p2",0))==NULL)exit(FALSE);

 control->ioa_Request.io_Message.mn_Node.ln_Pri=10;
 control->ioa_Data=&sunit;
 control->ioa_Length=(ULONG)sizeof(sunit);

 if((OpenDevice(AUDIONAME,0L,control,0L))!=NULL)  {
  printf("Can't open Audio Device\n");
  exit(FALSE);
 }
 *unit0=((UBYTE)control->ioa_Request.io_Unit & mapleft);
 *unit1=((UBYTE)control->ioa_Request.io_Unit & mapright);

/* ===Set up the command structures=== */
```

Listing 7-11. (cont.)

```
 *finish=*control;

 finish->ioa_Request.io_Flags=IOF_QUICK;
 finish->ioa_Request.io_Command=ADCMD_FINISH;

 control->ioa_Request.io_Flags=IOF_QUICK;
 control->ioa_Request.io_Command=ADCMD_PERVOL;
}

fill_data(sO)
UBYTE *sO;
{
 double x;

 for(x=-(PI/2);x<=PI/2;x+=.1)  {
   *sO=(UBYTE)floor(100*sin(x));
   sO++;
  }
}

change_sound(loudness,period,control)
UWORD loudness,period;
struct IOAudio *control;
{
 control->ioa_Period=period;
 control->ioa_Volume=loudness;
 BeginIO(control);
 WaitIO(control);
}

sound_note(chnl,period,loudness)
struct IOAudio *chnl;
UWORD period,loudness;
{
  chnl->ioa_Request.io_Command=CMD_WRITE;
  chnl->ioa_Request.io_Flags=ADIOF_PERVOL|IOF_QUICK;
  chnl->ioa_Data=s_dataO;
  chnl->ioa_Cycles=O;
  chnl->ioa_Length=sizeof(s_dataO);
  chnl->ioa_Period= period;
  chnl->ioa_Volume=loudness;
}

grab_channel(sound,control,name)
struct IOAudio *sound,*control;
char *name;
{
 if((sound->ioa_Request.io_Message.mn_ReplyPort
   =CreatePort(name,O))==NULL)*sound=*control;
}
delay(intv)
long intv;
{
 long i;
```

Listing 7-11. (cont.)

```
 for(i=0;i<=intv;i++)
     ;
}
```

In our last example, Listing 7-12, we produce a sound using all four sound channels. This produces a full, rich, and complex tone. Two channels—0 and 2—sound from the left speaker, while the two remaining ones—1 and 3—are attached to the right speaker. Our complement of audio structures includes control and finish, as well as four sound structures: s0, s1, s2, and s3. Each of these latter structures is attached to a particular unit of the audio device. Once we initialize each one with the note we wish to play, we begin them one at a time. For effect, we start s0 then s2, and finally s1 and s3. The channels are shut down with a finish command, specifically sent to each unit in reverse order.

Listing 7-12. Using all four channels to produce sound.

```
#include <exec/types.h>
#include <exec/memory.h>
#include <hardware/custom.h>
#include <hardware/dmabits.h>
#include <libraries/dos.h>
#include <devices/audio.h>
#include <lattice/stdio.h>
#include <lattice/math.h>

extern struct MsgPort *CreatePort();
UBYTE s_data0[32],s_data1[32],s_data2[32],s_data3[32],
      sunit=0x0f;

main()
{
 int x,y,j;
 UBYTE u0=0x01,u1=0x02,u2=0x08,u3=0x04;
 struct IOAudio control,finish,s0,s1,s2,s3;

 setup(&control,&finish);

 s0=control;
 s0.ioa_Request.io_Unit=u0;

 s1=control;
 s1.ioa_Request.io_Unit=u1;

 s2=control;
 s2.ioa_Request.io_Unit=u2;

 s3=control;
 s3.ioa_Request.io_Unit=u3;
```

Listing 7-12. (cont.)

```
 grab_channel(&s0,&control,"c1");
 grab_channel(&s1,&control,"c2");
 grab_channel(&s2,&control,"c3");
 grab_channel(&s3,&control,"c4");

 fill_data(s_data0);
 fill_data(s_data1);
 fill_data(s_data2);
 fill_data(s_data3);

/* left channel setup */

 sound_note(&s0,(UWORD)508,(UWORD)30);
 sound_note(&s2,(UWORD)254,(UWORD)30);

/* right channel setup */

 sound_note(&s1,(UWORD)428,(UWORD)30);
 sound_note(&s3,(UWORD)214,(UWORD)30);

 BeginIO(&s0);
 delay(100000);
 BeginIO(&s2);
 delay(100000);
 BeginIO(&s1);
 delay(100000);
 BeginIO(&s3);
 delay(500000);

 finish.ioa_Request.io_Unit=u3;
 BeginIO(&finish);
 WaitIO(&finish);

 finish.ioa_Request.io_Unit=u1;
 BeginIO(&finish);
 WaitIO(&finish);

 finish.ioa_Request.io_Unit=u2;
 BeginIO(&finish);
 WaitIO(&finish);

 finish.ioa_Request.io_Unit=u0;
 BeginIO(&finish);
 WaitIO(&finish);

 CloseDevice(&control);
}

setup(control,finish)
struct IOAudio *control,*finish;
{
   .
if((control->ioa_Request.io_Message.mn_ReplyPort
```

Listing 7-12. (cont.)

```
    =CreatePort("p1",0))==NULL)exit(FALSE);

  if((finish->ioa_Request.io_Message.mn_ReplyPort
    =CreatePort("p2",0))==NULL)exit(FALSE);

  control->ioa_Request.io_Message.mn_Node.ln_Pri=10;
  control->ioa_Data=&sunit;
  control->ioa_Length=(ULONG)sizeof(sunit);

  if((OpenDevice(AUDIONAME,0L,control,0L))!=NULL)  {
   printf("Can't open Audio Device\n");
   exit(FALSE);
  }

/* ===Set up the command structures=== */

  *finish=*control;

  finish->ioa_Request.io_Flags=IOF_QUICK;
  finish->ioa_Request.io_Command=ADCMD_FINISH;

  control->ioa_Request.io_Flags=IOF_QUICK;
  control->ioa_Request.io_Command=ADCMD_PERVOL;
}

fill_data(s0)
UBYTE *s0;
{
 double x;

 for(x=-(PI/2);x<=PI/2;x+=.1)  {
   *s0=(UBYTE)floor(100*sin(x));
   s0++;
  }
}

change_sound(loudness,period,control)
UWORD loudness,period;
struct IOAudio *control;
{
 control->ioa_Period=period;
 control->ioa_Volume=loudness;
 BeginIO(control);
 WaitIO(control);
}

sound_note(chnl,period,loudness)
struct IOAudio *chnl;
UWORD period,loudness;
{
  chnl->ioa_Request.io_Command=CMD_WRITE;
  chnl->ioa_Request.io_Flags=ADIOF_PERVOL|IOF_QUICK;
  chnl->ioa_Data=s_data0;
  chnl->ioa_Cycles=0;
```

Listing 7-12. (cont.)

```
  chnl->ioa_Length=sizeof(s_data0);
  chnl->ioa_Period= period;
  chnl->ioa_Volume=loudness;
}

grab_channel(sound,control,name)
struct IOAudio *sound,*control;
char *name;
{
 if((sound->ioa_Request.io_Message.mn_ReplyPort
  =CreatePort(name,0))==NULL)*sound=*control;
}
delay(intv)
long intv;
{
 long i;
 for(i=0;i<=intv;i++)
     ;
}
```

Summary

Through the examples in this chapter, you have seen several ways to access the sound subsystem on the Amiga. You can go from the very simple—sounding a note on a single channel—to the complex—using all channels to produce a full, stereophonic sound. Because these channels are accessed through a standard device, they are readily available in the Amiga's multitasking environment. Thus, sound can be added as an incidental effect to an application (e.g., a game), or it can be added to a graphics program to produce an enhanced multimedia effect.

There are other capabilities of the sound subsystem that are beyond the scope of this chapter's discussion. For the programmer willing to go deep into the hardware level, it is possible to set up the sound circuitry so that one channel's output will modulate another. Both amplitude and frequency modulation are possible. In addition, as with all devices that can participate in the Amiga's multitasking, you can coordinate the audio device among competing tasks. It is possible to lock the channels and use allocation commands to arbitrate between users of different priorities. It is even possible, with some add-on hardware, to use the Amiga in a MIDI network where it can function as both a controller and as another instrument.

The sound capabilities of the Amiga make it an outstanding machine for any kind of music programming tasks. As we have seen, it is a powerful programming tool, yet that power is easy to access.

Artificial Speech

Chapter 8

The Nature of Speech
The Translator Library
The Narrator Device
Experimenting with the Narrator
Summary

The Amiga talks! Included in the operating system software is a complete speech synthesis system that works in conjunction with the sound circuitry and the audio device to produce high quality easily understood speech. This offers an important alternative output to the more traditional monitor or printer. Using this feature is a simple operation and one that is consistent with the Amiga's other I/O devices.

The Nature of Speech

Human speech is created by the use of the vocal track system. A complete explanation would be impossible here and no more than a cursory glance need be given. Basically, the human voice starts out as a tone rich in harmonics. This tone is modulated to produce the different sounds that are recognized as human language. The original tone is produced by the vocal chords, but the throat, mouth, teeth, and tongue also have an important part to play in speaking.

There are several important parameters that are involved in any act of speaking. However, it is not necessary to create a complete simulation of the upper human anatomy to produce an intelligible sound. Certain standard sets of frequencies, the *formants*, are used in various combinations to produce nearly all the sounds of human speech. A computer simulation need only be concerned with these. You can create these formant values mathematically in the computer and end up with quite intelligible language. This is precisely what the Amiga does.

The Amiga's unique sound creation subsystem makes the simulation of human formant values not just practical, but easy as well. Recall that the sound circuitry consists, not of specialized music creation chips, but of general purpose digital-to-analog converters. Any sound can be easily mimicked using this system. The sound requirements for speech are less stringent than those for music synthesis and are well within the capabilities of these specialized chips.

Although it is possible to create speech just by manipulating the Amiga's sound subsystem, the necessity for such direct and low-level access has been obviated by the creation within the operating system of a "speech synthesis" subsystem. This is yet another example of the advanced nature of the Amiga. The speech device is on the same level of access as the more mundane printer drivers!

Phonemes and Syllables

Human speech is a function of the physical characteristics which produce it—the hardware, as it were. It is necessary to create a simulation of this hardware to create the oscillating current that drives the loudspeakers, which finally allow you to hear the sounds. However, first you need some kind of connection with the printed word that will drive this synthesis. What you want is the ability to type a line or a paragraph of text and have the Amiga speak it. The connecting link is the *phoneme*; this is a higher level construction than the actual sounds themselves.

A phoneme is a basic unit of linguistic sound, which is peculiar to and defines a particular language. The human vocal tract can make a large variety of noises, tones, and other sonic objects. Each human language restricts itself to a very small subset of these sounds; these are the phonemes. Speech synthesizers, then, need only be able to generate a small set to create intelligible speech.

The phoneme is also related to the written word. There is not necessarily a one-to-one correspondence between syllables and phonemes, but there is often at least a rough correlation. Besides creating the sounds, a speech synthesis system must be able to translate the written text, syllable by syllable, into proper phonemes, which can then be handled by the sound generator subsystem.

Each of these problems—translation and speech—is a significant one. The algorithms are not trivial, and, in fact, there is a great deal of controversy over which approaches are most proper. The Amiga tackles translation and speech by creating two related subsystems:

1. The *translator library* handles the encoding of the written word into phonemes.
2. The *narrator device* produces the speech.

In the following pages we will concentrate on how to use these two devices, both independently and together.

The Translator Library

The first task of the speech producing process is to divide the written word into its constituent phonemes. The translator library is a disk-resident object that can help accomplish this job. It takes as input a string of text and

produces as output a string of text translated into a phonetic language that can be used by the narrator device. This translation is based on a number of factors. Essentially, the string is divided into words and syllables, and the syllables are matched with their corresponding phonetic equivalents. However, the spelling of English is not fully phonetic, so some exception checking is also completed. The stress on individual words and the sentence intonation are partially controlled by various punctuation marks recognized by the speech subsystem.

You are free to use your own translation functions and bypass the translator library altogether. There are circumstances where this is an attractive alternative. But realize that accurate translation is not a simple proposition. There are many homophones in English and even more words that do not sound as they are spelled. On top of all this, speed is essential; any algorithm must be relatively quick, to carry on even a simulated conversation.

The translator library has but a single function to accomplish its task:

```
Translate(in,in_length,out,out_length);
```

where

in points to a character string containing the line to be translated.

in_length indicates the number of characters in the text string.

out is a character array that accepts the phonetic equivalent.

out_length is the number of characters in the output string.

Although we will talk more about using the phonetic alphabet later, when we discuss its direct application, note here that, in general, the phonetic string is significantly longer than the initial text.

Before you can use the services of the translator library, you must open it and load its contents into memory. You must also tell the operating system where it resides in memory. All of this is accomplished by the same *OpenLibrary()* function, which you have used already to gain access to other system resources. This function returns the address of the newly available library. The value must be stored in the global variable:

```
struct Library *TranslatorBase;
```

This is similar to both Intuition and the graphics libraries. Once the library is open, calls to *Translate()* can be made repeatedly. When all translation activity is finished, a call to *CloseLibrary()* allows the operating system to regain the used memory. One further note: the system expects to find the translator library in the virtual directory LIBS:. It may be necessary to reassign this directory to whatever physical directory actually contains the library.

Listing 8-1 illustrates a simple program that translates a single line of text into a single phonetic line. The phonetic line is then printed out as a character string rather than being sent to the narrator device. This program only demonstrates how this library can be used. It is for instructional purposes only. One function, *get_phoneme()*, takes the same set of parameters as the *Translate()* function itself—in and out strings and their respective

lengths. The translator library is opened within the scope of the function, the translation is made, and then the library is closed. The error checking in the *get_phoneme()* function is minimal; it returns an integer value indicating success or failure. In the program example, we close the library immediately after the translation into phonemes, because it is a good idea to keep hold of a resource such as a library for as little time as possible. This increases the efficiency of memory usage, which, in a multitasking environment, in turn makes for fewer delays and faster program execution. In fact, closing a library doesn't necessarily mean that the library code is swapped out to disk. If the space in memory is not needed, it remains there, waiting for its next use.

Listing 8-1. Use of the translator library to convert a string of characters into a string of phonemes.

```
#define ERR 1
#define SUCCESS 0

#include <exec/types.h>
#include <exec/exec.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/memory.h>
#include <exec/interrupts.h>
#include <exec/ports.h>
#include <exec/libraries.h>
#include <exec/io.h>
#include <exec/tasks.h>
#include <exec/execbase.h>
#include <libraries/translator.h>
#include <lattice/stdio.h>

struct Library *TranslatorBase;
extern struct Library *OpenLibrary();

main()
{

 UBYTE in_string[80],out_string[300];

 printf("enter string ");
 scanf("%s",in_string);



 if(get_phoneme(in_string,strlen(in_string),out_string,300)==ERR)
   exit(FALSE);

 printf("\n\nThe phoneme translation of %s is %s\n",in_string,out_string);


}
```

Listing 8-1. (cont.)

```
get_phoneme(in,inlen,out,outlen)
UBYTE *in,*out;
SHORT inlen,outlen;
{

 TranslatorBase=(struct Library *)
                OpenLibrary("translator.library",1);

 if(TranslatorBase==NULL)
    return(ERR);

 if((Translate(in,inlen,out,outlen))!=0)
    return(ERR);

 CloseLibrary(TranslatorBase);

 return(SUCCESS);

}
```

There are a few points that may not be obvious from either the discussion of the *Translate()* function or its program example. *Translate()* always works on a sentence—a string of text. If a single word or even a single sound is translated, it is translated as a sentence. This has an effect on the intonation of the word when it is finally produced by the narrator device. Once a string of phonemes has been produced by this function, the string can be edited as any other text string; thus, you can fine tune the speech that is finally uttered without having to create your own translation algorithms.

The Narrator Device

The next step, once you have translated text into a phonetic representation, is to call up the Amiga's hardware, in order to pronounce each one of the phonemes. This capability is contained in a specialized device driver, the *Narrator*. There are many advantages in making this a device driver; a major one is that, as a device driver, the Narrator can participate fully in the Amiga's multitasking environment. The processes producing speech can run in the background in concert with other system processes rather than taking over the entire machine. Possibilities are endless, but a particular combination that comes readily to mind is the integration of sound with the fine graphics displays available on the Amiga.

Aside from the somewhat flashy (and practical) graphics and sound shows possible, other more stolid (but no less important) possibilities become apparent. Sound can be wedded to a database program and thus can tell you what is found in a search. Speech in conjunction with a program help facility

can add an important dimension of performance to an application program. The narrator device, although simple in operation, is an important subsystem on the Amiga and one that is not often found on microcomputers.

Splitting the two functions—speech and translation—is yet another indication of the sophistication of the Amiga. This allows a great degree of flexibility. For example, if you have a need to say only a few phrases or repeated sentences, you can save yourself the overhead of the translator library, and hard code the phonetic representation into your program. If you need an overall conversion facility, it is available. You can also replace the translation facility with one of your own design, or even add layers of preprocessing.

Since the Narrator is a device, access is through the Amiga's message facility. You command the device by sending messages, and it returns messages to indicate the completion of the required task or to report important status information. The first level of access is through a modified message structure:

```
struct narrator_rb {
   struct IOStdReq message;
   UWORD  rate,
          pitch,
          mode,
          sex;
   UBYTE  *ch_masks;
   UWORD  nm_masks,
          volume,
          sampfreq;
   UBYTE  mouths,
          chanmask,
          numchan,
          fill;
};
```

Message is a standard I/O structure to interface with the message passing system. The *ch_masks* and *nm_masks* are concerned with channel allocation in the audio device. Note that *chanmask* and *numchan* are set by the system rather than the program. The *mouths* field is used in conjunction with the related mouth_rb structure; we will talk more about this in a moment.

The *rate* field sets the speed of the uttered speech; it is measured in words per minute. The range of this parameter varies from 40 to 400 words per minute. The default rate is set at 150. The *volume* field ranges from 0 to 64 and affects the loudness of the speech sounds. The default value is 64, while a value of 0 indicates the device is turned off.

The *mode* field affects the intonation and stress of the artificial speech produced. There are two defined modes:

NATURALF0 produces an inflected speech that attempts to model an ordinary English speaker's natural intonations.

ROBOTICF0 sets the Narrator to produce speech in a monotone—a steady, unvarying pitch with no inflection.

The default mode is NATURALF0.

Three fields can affect the sound quality of the Amiga's synthetic speech. The *pitch* field sets the base line frequency of the narrator device. Inflected speech varies around this value as a center point. If the mode is set to produce a monotone voice, this frequency is used without any variation. The range of the *pitch* field is from 65 to 320. The *sex* field takes either MALE or FEMALE; these defined constants cause the narrator device to produce speech that is characteristic of a man or a woman. The practical effect of this field is the production of a sound that is higher or lower. The *sex* field sets the overall frequency of the sound; the *pitch* value is a type of fine tuning control that varies the sound within this range.

Finally, *sampfreq* sets the sampling frequency of the audio device when it is rendering the speech sounds. Varying this between its extremes of 5000 and 28000 also indirectly affects the overall sound. Some interesting effects can be produced by playing with this field, but bear in mind that this is not the main purpose for the field. Its default value is 22200.

Listing 8-2 illustrates a program that converts a single line of text into an utterance. It consists of two functions.

1. **get_phoneme()** accesses the translator library.
2. **talk_to_me()** activates the narrator device.

The former has been imported from an earlier example (Listing 8-1); it translates the entered string into a phonetic representation and returns the result in the string variable *out_string*.

Listing 8-2. Use of the translator library and the narrator device to produce speech phonemes.

```
#define ERR 1
#define SUCCESS 0
#define REV 0

#include <exec/types.h>
#include <exec/exec.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/memory.h>
#include <exec/interrupts.h>
#include <exec/ports.h>
#include <exec/libraries.h>
#include <exec/io.h>
#include <exec/tasks.h>
#include <exec/execbase.h>
#include <libraries/translator.h>
#include <devices/audio.h>
#include <devices/narrator.h>
#include <lattice/stdio.h>

struct Library *TranslatorBase=NULL;
extern struct Library *OpenLibrary();
struct MsgPort *WPort,*RPort;
```

Listing 8-2. (cont.)

```
extern struct IORequest *CreateExtIO();
extern struct Library *OpenLibrary();
struct narrator_rb *wmes;
struct mouth_rb *rmes;

BYTE audChanMasks[]={3,5,10,12};

main()
{

 UBYTE in_string[80],out_string[300];

 printf("enter string ");
 gets(in_string);

 if(get_phoneme(in_string,strlen(in_string),out_string,300)==ERR)
   exit(FALSE);

 if(talk_to_me(out_string)==ERR)
   exit(FALSE);

 CloseDevice(wmes);

}

get_phoneme(in,inlen,out,outlen)
UBYTE *in,*out;
SHORT inlen,outlen;
{

 TranslatorBase=(struct Library *)
                 OpenLibrary("translator.library",REV);

 if(TranslatorBase==NULL)
    return(ERR);

 if((Translate(in,inlen,out,outlen))!=0)
    return(ERR);

 CloseLibrary(TranslatorBase);

 return(SUCCESS);

}

talk_to_me(speech)
UBYTE *speech;
{


 if((WPort=(struct MsgPort *)CreatePort(0,0))==NULL)
   return(ERR);

 if((RPort=(struct MsgPort *)CreatePort(0,0))==NULL)
```

Listing 8-2. (cont.)

```
    return(ERR);

  if((wmes=(struct narrator_rb *)
    CreateExtIO(WPort,sizeof(struct narrator_rb)))==NULL)
    return(ERR);

  if((rmes=(struct mouth_rb *)
    CreateExtIO(RPort,sizeof(struct narrator_rb)))==NULL)
    return(ERR);



  wmes->message.io_Command=CMD_WRITE;
  wmes->message.io_Data=(APTR)speech;
  wmes->message.io_Length=strlen(speech);
  wmes->ch_masks=audChanMasks;
  wmes->nm_masks=sizeof(audChanMasks);


  if(OpenDevice("narrator.device",0,wmes,0)!=0)
    return(ERR);

  wmes->mouths=0;
  wmes->volume=32;
  wmes->rate=20;
  wmes->sex=MALE;
  wmes->pitch=DEFPITCH;

  DoIO(wmes);

  return(SUCCESS);

}
```

The function *talk_to_me()* performs all the necessary steps to set up and use the narrator device. First we create a port to the device and attach the narrator_rb structure to it; this is accomplished by a call to *CreatePort()* and a subsequent call to *CreateExtIO()*. Both of these functions are general purpose system calls that are used whenever it is necessary to interact with the Exec kernel's underlying message passing system. The next step is to initialize the *wmes*, our narrator_rb struct, to properly interact with the narrator device. Most importantly, we set the *message.io_Command* field to CMD_WRITE, to indicate that we desire an output operation rather than input. This is a necessary prior step to the use of *OpenDevice()* to set the process in motion.

Once you have opened the narrator device, you are free to send command messages to it and wait for its activity; however, before you send a message, you must initialize it to the values on which you want it to operate. Foremost of these values is the string of phonemes that is to be pronounced; this goes

into the *message.io_Data* field. This field should be cast to an absolute address data type—APTR. The length of this field is put into *message.io_Length*. These two fields, along with the *message.io_Command* field, are part of the standard message structure. The other fields that need to be set are peculiar to the narrator_rb structure itself. These are explained above, and the example contains typical values.

Once you have translated a line of text, done the setup, and opened the device, you are ready to send an I/O request to the Narrator. In the example, we use the simplest call, *DoIO()*. This sends the command structure with its variables to the device, and then stops and waits for a reply. Once that reply has been obtained, we return to the main program and execute a call to *CloseDevice()*, before stopping the program. As we have noted before, it is very important to close unused resources with the Amiga; otherwise, you may run out of a most important resource—main memory.

The example in Listing 8-3 is a modification of the previous program. This program is set up to deal with more than one line of input. The primary modification is the creation of a third function, *set_to_talk()*, which handles all setup for the narrator device. This step is necessary, because we are going to send multiple messages to this device, but we need only open it once. Note that we call *set_to_talk()* outside the main program loop.

Listing 8-3. Use of Set_to_talk() function to allow an unlimited number of spoken lines. Speech is produced using the translator library and narrator device.

```
#define ERR 1
#define SUCCESS 0
#define REV 0

#include <exec/types.h>
#include <exec/exec.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/memory.h>
#include <exec/interrupts.h>
#include <exec/ports.h>
#include <exec/libraries.h>
#include <exec/io.h>
#include <exec/tasks.h>
#include <exec/execbase.h>
#include <libraries/translator.h>
#include <devices/audio.h>
#include <devices/narrator.h>
#include <lattice/stdio.h>

struct Library *TranslatorBase=NULL;
extern struct Library *OpenLibrary();
struct MsgPort *WPort,*RPort;
extern struct IORequest *CreateExtIO();
extern struct Library *OpenLibrary();
struct narrator_rb *wmes;
```

Listing 8-3. (cont.)

```
struct mouth_rb *rmes;

BYTE audChanMasks[]={3,5,10,12};

main()
{

 UBYTE in_string[80],out_string[300];

 if(set_to_talk()==ERR)
   exit(FALSE);

 for(;;)  {
   printf("enter string ");
   gets(in_string);

   if(!strcmp(in_string,"%halt"))
     break;


if(get_phoneme(in_string,strlen(in_string),out_string,300)==ERR)
     exit(FALSE);

   if(talk_to_me(out_string)==ERR)
     exit(FALSE);
  }

 CloseDevice(wmes);

}

get_phoneme(in,inlen,out,outlen)
UBYTE *in,*out;
SHORT inlen,outlen;
{

 TranslatorBase=(struct Library *)
                 OpenLibrary("translator.library",REV);

 if(TranslatorBase==NULL)
    return(ERR);

 if((Translate(in,inlen,out,outlen))!=0)
    return(ERR);

 CloseLibrary(TranslatorBase);

 return(SUCCESS);

}

talk_to_me(speech)
UBYTE *speech;
{
```

Listing 8-3. (cont.)

```
 wmes->message.io_Data=(APTR)speech;
 wmes->message.io_Length=strlen(speech);
 wmes->ch_masks=audChanMasks;
 wmes->nm_masks=sizeof(audChanMasks);


 wmes->mouths=0;
 wmes->volume=32;
 wmes->rate=20;
 wmes->sex=MALE;
 wmes->pitch=DEFPITCH;



 DoIO(wmes);


}


set_to_talk()
{
 if((WPort=(struct MsgPort *)CreatePort(0,0))==NULL)
   return(ERR);

 if((wmes=(struct narrator_rb *)
   CreateExtIO(WPort,sizeof(struct narrator_rb)))==NULL)
   return(ERR);

 wmes->message.io_Command=CMD_WRITE;

 if(OpenDevice("narrator.device",0,wmes,0)!=0)
   return(ERR);

 return(SUCCESS);
}
```

One important flaw in the two previous examples is that they do not take full advantage of the multitasking capabilities of the Amiga. Whenever a message is sent to the narrator device, the current program goes into a wait state until the message has been received and a reply sent. Since the driver for this device is independent of the calling program, it would make more sense to send the message and then continue processing. Earlier discussions of multitasking have shown that there are a number of ways to accomplish this. Listings 8-4 and 8-5 illustrate a multitasking format commonly used with the speech synthesis subsystem.

Listing 8-4. Multitasking format used with the speech synthesis subsystem. A single line is converted to phonemes, then spoken.

```
#define ERR 1
#define SUCCESS 0
#define REV 0

#include <exec/types.h>
#include <exec/exec.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/memory.h>
#include <exec/interrupts.h>
#include <exec/ports.h>
#include <exec/libraries.h>
#include <exec/io.h>
#include <exec/tasks.h>
#include <exec/execbase.h>
#include <libraries/translator.h>
#include <devices/audio.h>
#include <devices/narrator.h>
#include <lattice/stdio.h>

struct Library *TranslatorBase=NULL;
extern struct Library *OpenLibrary();
struct MsgPort *WPort,*RPort;
extern struct IORequest *CreateExtIO();
extern struct Library *OpenLibrary();
struct narrator_rb *wmes;
struct mouth_rb *rmes;

BYTE audChanMasks[]={3,5,10,12};

main()
{

 UBYTE in_string[80],out_string[300];

 printf("enter string ");
 gets(in_string);

 if(get_phoneme(in_string,strlen(in_string),out_string,300)==ERR)
   exit(FALSE);

 if(talk_to_me(out_string)==ERR)
   exit(FALSE);

 CloseDevice(wmes);

}

get_phoneme(in,inlen,out,outlen)
UBYTE *in,*out;
SHORT inlen,outlen;
```

Listing 8-4. (cont.)

```
{

 TranslatorBase=(struct Library *)
                 OpenLibrary("translator.library",REV);

 if(TranslatorBase==NULL)
    return(ERR);

 if((Translate(in,inlen,out,outlen))!=0)
    return(ERR);

 CloseLibrary(TranslatorBase);

 return(SUCCESS);

}

talk_to_me(speech)
UBYTE *speech;
{


 if((WPort=(struct MsgPort *)CreatePort(0,0))==NULL)
   return(ERR);

 if((RPort=(struct MsgPort *)CreatePort(0,0))==NULL)
   return(ERR);

 if((wmes=(struct narrator_rb *)
   CreateExtIO(WPort,sizeof(struct narrator_rb)))==NULL)
   return(ERR);

 if((rmes=(struct mouth_rb *)
   CreateExtIO(RPort,sizeof(struct narrator_rb)))==NULL)
   return(ERR);



 wmes->message.io_Command=CMD_WRITE;
 wmes->message.io_Data=(APTR)speech;
 wmes->message.io_Length=strlen(speech);
 wmes->ch_masks=audChanMasks;
 wmes->nm_masks=sizeof(audChanMasks);


 if(OpenDevice("narrator.device",0,wmes,0)!=0)
   return(ERR);

 wmes->mouths=0;
 wmes->volume=32;
 wmes->rate=20;
 wmes->sex=MALE;
 wmes->pitch=DEFPITCH;
```

Listing 8-4. (cont.)

```
  rmes->voice.message.io_Device=wmes->message.io_Device;
  rmes->voice.message.io_Unit=wmes->message.io_Unit;
  rmes->width=0;
  rmes->height=0;
  rmes->voice.message.io_Command=CMD_READ;
  rmes->voice.message.io_Error=0;


  SendIO(wmes);

  while (rmes->voice.message.io_Error!=ND_NoWrite)
    DoIO(rmes);

  return(SUCCESS);

}
```

Before delving headlong into a discussion of these two listings, we must explore another structure associated with the narrator device:

```
struct mouth_rb {
   struct narrator_rb voice;
   UBYTE  width,
          height,
          shape,
          pad;
};
```

This structure is used to send information back from the Narrator to the calling routine. Specifically, it returns two values, *width* and *height*, which can be used to produce an animated picture of a mouth. The narrator device calculates these two variables based on the phoneme it is now speaking. If these values are to be used, the mouth field in the narrator_rb structure must be set to a value other than 0.

Even if you are not interested in associating a screen image with the spoken word issuing from the computer, you can use the mouth_rb structure to set up a monitoring task that allows you to send messages to the Narrator, but not wait for their completion. This is illustrated in Listing 8-4. This program is similar to the earlier Listing 8-2; it accepts a single line as input, converts it to phonemes, and then speaks it. Here, however, we declare two associated structures: a narrator_rb and a mouth structure. To accommodate them, we open two ports: one to write to and one to read from. We open the device with the narrator_rb structure and then copy the *message_io.Device* and *message_io.Unit* to the mouth_rb structure. This insures that the two are linked during the I/O operations.

Once initialization is complete, we access the Narrator via a *SendIO()* command. This transmits our command message and then continues with the rest of the program. Meanwhile, a *DoIO()* operation is performed using the mouth_rb structure. When the Narrator has finally finished speaking the

entire message, it sets the *voice.message.Error* field to *ND_NoWrite*. These I/O operations are performed until this condition is met. Listing 8-5 also uses the *SendIO()* function and the dual structures, but in the context of a continuous loop in the main program.

Listing 8-5. Multitasking format used with the speech synthesis subsystem. An unlimited number of lines can be spoken.

```
#define ERR 1
#define SUCCESS 0
#define REV 0

#include <exec/types.h>
#include <exec/exec.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/memory.h>
#include <exec/interrupts.h>
#include <exec/ports.h>
#include <exec/libraries.h>
#include <exec/io.h>
#include <exec/tasks.h>
#include <exec/execbase.h>
#include <libraries/translator.h>
#include <devices/audio.h>
#include <devices/narrator.h>
#include <lattice/stdio.h>

struct Library *TranslatorBase=NULL;
extern struct Library *OpenLibrary();
struct MsgPort *WPort,*RPort;
extern struct IORequest *CreateExtIO();
extern struct Library *OpenLibrary();
struct narrator_rb *wmes;
struct mouth_rb *rmes;

BYTE audChanMasks[]={3,5,10,12};

main()
{

 UBYTE in_string[80],out_string[300];

 if(set_to_talk()==ERR)
   exit(FALSE);

 for(;;)  {
   printf("enter string ");
   gets(in_string);

   if(!strcmp(in_string,"%%"))
     break;


if(get_phoneme(in_string,strlen(in_string),out_string,300)==ERR)
```

Listing 8-5. (cont.)

```
     exit(FALSE);

   if(talk_to_me(out_string)==ERR)
     exit(FALSE);
  }

 CloseDevice(wmes);

}

get_phoneme(in,inlen,out,outlen)
UBYTE *in,*out;
SHORT inlen,outlen;
{

 TranslatorBase=(struct Library *)
                 OpenLibrary("translator.library",REV);

 if(TranslatorBase==NULL)
    return(ERR);

 if((Translate(in,inlen,out,outlen))!=0)
    return(ERR);

 CloseLibrary(TranslatorBase);

 return(SUCCESS);

}

talk_to_me(speech)
UBYTE *speech;
{
 wmes->message.io_Data=(APTR)speech;
 wmes->message.io_Length=strlen(speech);
 wmes->ch_masks=audChanMasks;
 wmes->nm_masks=sizeof(audChanMasks);


 wmes->mouths=0;
 wmes->volume=32;
 wmes->rate=20;
 wmes->sex=MALE;
 wmes->pitch=DEFPITCH;




 SendIO(wmes);

 while (rmes->voice.message.io_Error!=ND_NoWrite)
   DoIO(rmes);

}
```

Listing 8-5. (cont.)

```
set_to_talk()
{
 if((WPort=(struct MsgPort *)CreatePort(0,0))==NULL)
   return(ERR);

 if((RPort=(struct MsgPort *)CreatePort(0,0))==NULL)
   return(ERR);

 if((wmes=(struct narrator_rb *)
   CreateExtIO(WPort,sizeof(struct narrator_rb)))==NULL)
   return(ERR);

 if((rmes=(struct mouth_rb *)
   CreateExtIO(RPort,sizeof(struct narrator_rb)))==NULL)
   return(ERR);

 wmes->message.io_Command=CMD_WRITE;

 if(OpenDevice("narrator.device",0,wmes,0)!=0)
   return(ERR);

 rmes->voice.message.io_Device=wmes->message.io_Device;
 rmes->voice.message.io_Unit=wmes->message.io_Unit;
 rmes->width=0;
 rmes->height=0;
 rmes->voice.message.io_Command=CMD_READ;
 rmes->voice.message.io_Error=0;

 return(SUCCESS);
}
```

Experimenting with the Narrator

Now that you understand the basic operation of the speech synthesis subsystem on the Amiga, it is important to also consider the effects of varying the parameters that are sent to this device. Although a great deal can be done with just the basic operation—the speech, as it stands, is clear and easily understandable—slight modifications to the default values can provide even more controlled performance. It is even possible to correct some of the ambiguities that are understandably found in this complicated set of procedures.

Listing 8-6. Use of set_params() function to set the parameters of speech.

```
#define ERR 1
#define SUCCESS 0
#define REV 0
```

Listing 8-6. (cont.)

```
#include <exec/types.h>
#include <exec/exec.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/memory.h>
#include <exec/interrupts.h>
#include <exec/ports.h>
#include <exec/libraries.h>
#include <exec/io.h>
#include <exec/tasks.h>
#include <exec/execbase.h>
#include <libraries/translator.h>
#include <devices/audio.h>
#include <devices/narrator.h>
#include <lattice/stdio.h>

struct Library *TranslatorBase=NULL;
extern struct Library *OpenLibrary();
struct MsgPort *WPort,*RPort;
extern struct IORequest *CreateExtIO();
extern struct Library *OpenLibrary();
struct narrator_rb *wmes;
struct mouth_rb *rmes;

BYTE audChanMasks[]={3,5,10,12};

main()
{

 UBYTE in_string[80],out_string[300];
 UWORD volume=55,rate=20;

 if(set_to_talk()==ERR)
   exit(FALSE);

 for(;;)  {
   printf("enter string ");
   gets(in_string);

   if(!strcmp(in_string,"%halt"))
     break;

   if(!strcmp(in_string,"%set")) {
     set_params(&volume,&rate);
     continue;
    }


if(get_phoneme(in_string,strlen(in_string),out_string,300)==ERR)
     exit(FALSE);

   if(talk_to_me(out_string,volume,rate)==ERR)
     exit(FALSE);
  }
```

Listing 8-6. (cont.)

```
 CloseDevice(wmes);

}

get_phoneme(in,inlen,out,outlen)
UBYTE *in,*out;
SHORT inlen,outlen;
{

 TranslatorBase=(struct Library *)
                 OpenLibrary("translator.library",REV);

 if(TranslatorBase==NULL)
    return(ERR);

 if((Translate(in,inlen,out,outlen))!=0)
    return(ERR);

 CloseLibrary(TranslatorBase);

 return(SUCCESS);

}

talk_to_me(speech,vol,rate)
UBYTE *speech;
UWORD vol,rate;
{

 wmes->message.io_Data=(APTR)speech;
 wmes->message.io_Length=strlen(speech);
 wmes->ch_masks=audChanMasks;
 wmes->nm_masks=sizeof(audChanMasks);

 wmes->mouths=0;
 wmes->volume=vol;
 wmes->rate=rate;
 wmes->sex=MALE;
 wmes->pitch=DEFPITCH;

 SendIO(wmes);

 while (rmes->voice.message.io_Error!=ND_NoWrite)
   DoIO(rmes);
}

set_to_talk()
{
 if((WPort=(struct MsgPort *)CreatePort(0,0))==NULL)
   return(ERR);

 if((RPort=(struct MsgPort *)CreatePort(0,0))==NULL)
   return(ERR);
```

Listing 8-6. (cont.)

```
 if((wmes=(struct narrator_rb *)
   CreateExtIO(WPort,sizeof(struct narrator_rb)))==NULL)
   return(ERR);

 if((rmes=(struct mouth_rb *)
   CreateExtIO(RPort,sizeof(struct narrator_rb)))==NULL)
   return(ERR);

 wmes->message.io_Command=CMD_WRITE;

 if(OpenDevice("narrator.device",0,wmes,0)!=0)
   return(ERR);

 rmes->voice.message.io_Device=wmes->message.io_Device;
 rmes->voice.message.io_Unit=wmes->message.io_Unit;
 rmes->width=0;
 rmes->height=0;
 rmes->voice.message.io_Command=CMD_READ;
 rmes->voice.message.io_Error=0;

 return(SUCCESS);
}

set_params(vol,rate)
UWORD *vol,*rate;
{
 int x,y;

 printf("volume==>");
 scanf("%d",&x);

 printf("rate  ==>");
 scanf("%d",&y);

 *vol=(UWORD)x;
 *rate=(UWORD)y;

}
```

Listing 8-6 contains a prototype program that allows us to enter values for the volume and rate fields of the narrator_rb structure. It is similar in design to the example in Listing 8-7, but we have added a fourth function, *set_params()*. This new function prompts the user to provide values for these fields, and then passes them back to the main part of the program. *Talk_to_me()* has also been modified to accept these parameters. This is a very simple example. There are no default values for these fields; they must be set by the user before the loop in *main()* begins. *Set_Params()* is the first function call in the program. Note, too, that the assignments to the fields in the narrator_rb structure are done after the *OpenDevice()* call but before any I/O function

is accessed. Although we haven't provided code for error checking on entered values, the example illustrates a way to better understand the results of varying the Narrator values.

Listing 8-7. Addition of pitch, mode and sex values to set_params() function. This expands the range of speech parameters.

```
#define ERR 1
#define SUCCESS 0
#define REV 0

#include <exec/types.h>
#include <exec/exec.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/memory.h>
#include <exec/interrupts.h>
#include <exec/ports.h>
#include <exec/libraries.h>
#include <exec/io.h>
#include <exec/tasks.h>
#include <exec/execbase.h>
#include <libraries/translator.h>
#include <devices/audio.h>
#include <devices/narrator.h>
#include <lattice/stdio.h>

struct Library *TranslatorBase=NULL;
extern struct Library *OpenLibrary();
struct MsgPort *WPort,*RPort;
extern struct IORequest *CreateExtIO();
extern struct Library *OpenLibrary();
struct narrator_rb *wmes;
struct mouth_rb *rmes;

BYTE audChanMasks[]={3,5,10,12};

main()
{

 UBYTE in_string[80],out_string[300];
 UWORD volume=55,rate=20,pitch=DEFPITCH,mode=DEFMODE,sex=DEFSEX;

 if(set_to_talk()==ERR)
   exit(FALSE);

 for(;;)  {
   printf("enter string ");
   gets(in_string);

   if(!strcmp(in_string,"%halt"))
     break;

   if(!strcmp(in_string,"%set")) {
```

Listing 8-7. (cont.)

```
     set_params(&volume,&rate,&pitch,&mode,&sex);
     continue;
    }


if(get_phoneme(in_string,strlen(in_string),out_string,300)==ERR)
     exit(FALSE);

   if(talk_to_me(out_string,volume,rate,pitch,mode,sex)==ERR)
     exit(FALSE);
  }

 CloseDevice(wmes);

}

get_phoneme(in,inlen,out,outlen)
UBYTE *in,*out;
SHORT inlen,outlen;
{

 TranslatorBase=(struct Library *)
                 OpenLibrary("translator.library",REV);

 if(TranslatorBase==NULL)
    return(ERR);

 if((Translate(in,inlen,out,outlen))!=0)
    return(ERR);

 CloseLibrary(TranslatorBase);

 return(SUCCESS);

}

talk_to_me(speech,vol,rate,pitch,mode,sex)
UBYTE *speech;
UWORD vol,rate,pitch,mode,sex;
{

 wmes->message.io_Data=(APTR)speech;
 wmes->message.io_Length=strlen(speech);
 wmes->ch_masks=audChanMasks;
 wmes->nm_masks=sizeof(audChanMasks);

 wmes->mouths=0;
 wmes->volume=vol;
 wmes->rate=rate;
 wmes->sex=sex;
 wmes->pitch=pitch;
 wmes->mode=mode;

 SendIO(wmes);
```

Listing 8-7. (cont.)

```
 while (rmes->voice.message.io_Error!=ND_NoWrite)
   DoIO(rmes);
}

set_to_talk()
{
 if((WPort=(struct MsgPort *)CreatePort(0,0))==NULL)
   return(ERR);

 if((RPort=(struct MsgPort *)CreatePort(0,0))==NULL)
   return(ERR);

 if((wmes=(struct narrator_rb *)
   CreateExtIO(WPort,sizeof(struct narrator_rb)))==NULL)
   return(ERR);

 if((rmes=(struct mouth_rb *)
   CreateExtIO(RPort,sizeof(struct narrator_rb)))==NULL)
   return(ERR);

 wmes->message.io_Command=CMD_WRITE;

 if(OpenDevice("narrator.device",0,wmes,0)!=0)
   return(ERR);

 rmes->voice.message.io_Device=wmes->message.io_Device;
 rmes->voice.message.io_Unit=wmes->message.io_Unit;
 rmes->width=0;
 rmes->height=0;
 rmes->voice.message.io_Command=CMD_READ;
 rmes->voice.message.io_Error=0;

 return(SUCCESS);
}

set_params(vol,rate,pitch,mode,sex)
UWORD *vol,*rate,*pitch,*mode,*sex;
{
 int x,y,z;
 char ch[80];

 printf("volume==>");
 scanf("%d",&x);

 printf("rate  ==>");
 scanf("%d",&y);

 *vol=(UWORD)x;
 *rate=(UWORD)(MINRATE+y);

 printf("pitch ==>");
 scanf("%d",&z);

 *pitch=z;
```

Listing 8-7. (cont.)

```
 printf("mode  ==>");
 scanf("%s",ch);

 if(!strcmp(ch,"inflected"))
   *mode=NATURALFO;
 if(!strcmp(ch,"monotone"))
   *mode=ROBOTICFO;

 printf("sex    ==>");
 scanf("%s",ch);

 if(!strcmp(ch,"male"))
   *sex=MALE;

 if(!strcmp(ch,"female"))
   *sex=FEMALE;

}
```

In Listing 8-7, we have a program almost identical to 8-6. Here, however, we have added the *pitch*, *mode*, and *sex* values to both the *set_params()* and *talk_to_me()* functions. This gives a greater range of parameters with which to experiment when producing speech. The example described in Listing 8-8 adds more complexity. In this program we also enter the sampling frequency, *sampfreq*, in the narrator_rb structure. Additional features include:

- A logical structure that allows us to call the *set_params()* function at any time
- Support for default values. It is no longer necessary to enter values for each parameter if we want to vary just one.

This is a more complete example, which can be used directly to play with the speech synthesizer values or as inspiration for embedded functions that bring the capability of speech to other kinds of programs.

Listing 8-8. Expanded use of set_params() function. Sampling frequency is included and default values are supported.

```
#define ERR 1
#define SUCCESS 0
#define REV 0

#include <exec/types.h>
#include <exec/exec.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/memory.h>
#include <exec/interrupts.h>
```

Listing 8-8. (cont.)

```
#include <exec/ports.h>
#include <exec/libraries.h>
#include <exec/io.h>
#include <exec/tasks.h>
#include <exec/execbase.h>
#include <libraries/translator.h>
#include <devices/audio.h>
#include <devices/narrator.h>
#include <lattice/stdio.h>

struct Library *TranslatorBase=NULL;
extern struct Library *OpenLibrary();
struct MsgPort *WPort,*RPort;
extern struct IORequest *CreateExtIO();
extern struct Library *OpenLibrary();
struct narrator_rb *wmes;
struct mouth_rb *rmes;

BYTE audChanMasks[]={3,5,10,12};

main()
{

 UBYTE in_string[80],out_string[300];
 UWORD volume=55,rate=20,pitch=DEFPITCH,mode=DEFMODE,
       sex=DEFSEX,freq=DEFFREQ;

 if(set_to_talk()==ERR)
   exit(FALSE);

 for(;;)  {
   printf("enter string ");
   gets(in_string);

   if(!strcmp(in_string,"%halt"))
     break;

   if(!strcmp(in_string,"%set")) {
     set_params(&volume,&rate,&pitch,&mode,&sex,&freq);
     continue;
    }


if(get_phoneme(in_string,strlen(in_string),out_string,300)==ERR)
     exit(FALSE);


if(talk_to_me(out_string,volume,rate,pitch,mode,sex,freq)==ERR)
       exit(FALSE);
  }

 CloseDevice(wmes);

}
```

Listing 8-8. (cont.)

```
get_phoneme(in,inlen,out,outlen)
UBYTE *in,*out;
SHORT inlen,outlen;
{

 TranslatorBase=(struct Library *)
                 OpenLibrary("translator.library",REV);

 if(TranslatorBase==NULL)
    return(ERR);

 if((Translate(in,inlen,out,outlen))!=0)
    return(ERR);

 CloseLibrary(TranslatorBase);

 return(SUCCESS);

}

talk_to_me(speech,vol,rate,pitch,mode,sex,freq)
UBYTE *speech;
UWORD vol,rate,pitch,mode,sex,freq;
{

 wmes->message.io_Data=(APTR)speech;
 wmes->message.io_Length=strlen(speech);
 wmes->ch_masks=audChanMasks;
 wmes->nm_masks=sizeof(audChanMasks);

 wmes->mouths=0;
 wmes->volume=vol;
 wmes->rate=rate;
 wmes->sex=sex;
 wmes->pitch=pitch;
 wmes->mode=mode;
 wmes->sampfreq=freq;

 SendIO(wmes);

 while (rmes->voice.message.io_Error!=ND_NoWrite)
   DoIO(rmes);
}

set_to_talk()
{
 if((WPort=(struct MsgPort *)CreatePort(0,0))==NULL)
   return(ERR);

 if((RPort=(struct MsgPort *)CreatePort(0,0))==NULL)
   return(ERR);

 if((wmes=(struct narrator_rb *)
```

Listing 8-8. (cont.)

```
    CreateExtIO(WPort,sizeof(struct narrator_rb)))==NULL)
    return(ERR);

 if((rmes=(struct mouth_rb *)
    CreateExtIO(RPort,sizeof(struct narrator_rb)))==NULL)
    return(ERR);

 wmes->message.io_Command=CMD_WRITE;

 if(OpenDevice("narrator.device",0,wmes,0)!=0)
    return(ERR);

 rmes->voice.message.io_Device=wmes->message.io_Device;
 rmes->voice.message.io_Unit=wmes->message.io_Unit;
 rmes->width=0;
 rmes->height=0;
 rmes->voice.message.io_Command=CMD_READ;
 rmes->voice.message.io_Error=0;

 return(SUCCESS);
}

set_params(vol,rate,pitch,mode,sex,freq)
UWORD *vol,*rate,*pitch,*mode,*sex,*freq;
{
 int x;
 char ch[80];

 printf("volume==>");
 gets(ch);
 if(ch[0]=='\0')
  ;
 else  {
  x=atoi(ch);
  *vol=x;
 }

 printf("rate  ==>");
 gets(ch);
 if(ch[0]=='\0')
  ;
 else  {
  x=atoi(ch);
  *rate=x;
 }

 printf("pitch ==>");
 gets(ch);
 if(ch[0]=='\0')
  ;
 else  {
  x=atoi(ch);
  *pitch=x;
 }
```

Listing 8-8. (cont.)

```
 printf("mode  ==>");
 gets(ch);
 if(ch[0]=='\0')
  ;
  else if(!strcmp(ch,"inflected"))
        *mode=NATURALF0;
 else if(!strcmp(ch,"monotone"))
        *mode=ROBOTICF0;

 printf("sex    ==>");
 gets(ch);
 if(ch[0]=='\0')
  ;
 else if(!strcmp(ch,"male"))
         *sex=MALE;
 else if(!strcmp(ch,"female"))
         *sex=FEMALE;

 printf("sample freq==>");
 gets(ch);

 if(ch[0]=='\0')
  ;
 else  {
    x=atoi(ch);
    *freq=x;
  }
}
```

As mentioned earlier, it is possible to do without the services of the translator library altogether and enter a string of phonetic characters directly. This capability is added to Listing 8-6 in Listing 8-9. Creating your own phoneme streams allows a more accurate representation of the sound of certain words, particularly uncommon ones. In addition, it allows you to manipulate the stress and intonation of individual words and sentences.

Listing 8-9. Addition of optional direct input of phonetics to speech synthesis program.

```
#define ERR 1
#define SUCCESS 0
#define REV 0

#include <exec/types.h>
#include <exec/exec.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/memory.h>
#include <exec/interrupts.h>
```

Listing 8-9. (cont.)

```
#include <exec/ports.h>
#include <exec/libraries.h>
#include <exec/io.h>
#include <exec/tasks.h>
#include <exec/execbase.h>
#include <libraries/translator.h>
#include <devices/audio.h>
#include <devices/narrator.h>
#include <lattice/stdio.h>

struct Library *TranslatorBase=NULL;
extern struct Library *OpenLibrary();
struct MsgPort *WPort,*RPort;
extern struct IORequest *CreateExtIO();
extern struct Library *OpenLibrary();
struct narrator_rb *wmes;
struct mouth_rb *rmes;

BYTE audChanMasks[]={3,5,10,12};

main()
{

 UBYTE in_string[80],out_string[300];
 UWORD volume=55,rate=20,pitch=DEFPITCH,mode=DEFMODE,
       sex=DEFSEX,freq=DEFFREQ;


 if(set_to_talk()==ERR)
   exit(FALSE);

 for(;;)  {
   printf("enter string ");
   gets(in_string);

   if(!strcmp(in_string,"%halt"))
     break;

   if(!strcmp(in_string,"%set")) {
     set_params(&volume,&rate,&pitch,&mode,&sex,&freq);
     continue;
    }

   if(!strcmp(in_string,"%direct"))  {
     printf(">>");
     gets(out_string);
    }
   else

if(get_phoneme(in_string,strlen(in_string),out_string,300)==ERR)
       exit(FALSE);
```

Listing 8-9. (cont.)

```
if(talk_to_me(out_string,volume,rate,pitch,mode,sex,freq)==ERR)
     exit(FALSE);
  }

 CloseDevice(wmes);

}

get_phoneme(in,inlen,out,outlen)
UBYTE *in,*out;
SHORT inlen,outlen;
{

 TranslatorBase=(struct Library *)
                 OpenLibrary("translator.library",REV);

 if(TranslatorBase==NULL)
    return(ERR);

 if((Translate(in,inlen,out,outlen))!=0)
    return(ERR);

 CloseLibrary(TranslatorBase);

 return(SUCCESS);

}

talk_to_me(speech,vol,rate,pitch,mode,sex,freq)
UBYTE *speech;
UWORD vol,rate,pitch,mode,sex,freq;
{

 wmes->message.io_Data=(APTR)speech;
 wmes->message.io_Length=strlen(speech);
 wmes->ch_masks=audChanMasks;
 wmes->nm_masks=sizeof(audChanMasks);

 wmes->mouths=0;
 wmes->volume=vol;
 wmes->rate=rate;
 wmes->sex=sex;
 wmes->pitch=pitch;
 wmes->mode=mode;
 wmes->sampfreq=freq;

 SendIO(wmes);

 while (rmes->voice.message.io_Error!=ND_NoWrite)
   DoIO(rmes);
}

set_to_talk()
```

Listing 8-9. (cont.)

```
{
 if((WPort=(struct MsgPort *)CreatePort(0,0))==NULL)
   return(ERR);

 if((RPort=(struct MsgPort *)CreatePort(0,0))==NULL)
   return(ERR);

 if((wmes=(struct narrator_rb *)
   CreateExtIO(WPort,sizeof(struct narrator_rb)))==NULL)
   return(ERR);

 if((rmes=(struct mouth_rb *)
   CreateExtIO(RPort,sizeof(struct narrator_rb)))==NULL)
   return(ERR);

 wmes->message.io_Command=CMD_WRITE;

 if(OpenDevice("narrator.device",0,wmes,0)!=0)
   return(ERR);

 rmes->voice.message.io_Device=wmes->message.io_Device;
 rmes->voice.message.io_Unit=wmes->message.io_Unit;
 rmes->width=0;
 rmes->height=0;
 rmes->voice.message.io_Command=CMD_READ;
 rmes->voice.message.io_Error=0;

 return(SUCCESS);
}

set_params(vol,rate,pitch,mode,sex,freq)
UWORD *vol,*rate,*pitch,*mode,*sex,*freq;
{
 int x;
 char ch[80];

 printf("volume==>");
 gets(ch);
 if(ch[0]=='\0')
  ;
 else  {
  x=atoi(ch);
  *vol=x;
 }

 printf("rate  ==>");
 gets(ch);
 if(ch[0]=='\0')
  ;
 else  {
  x=atoi(ch);
  *rate=x;
 }
```

Listing 8-9. (cont.)

```
 printf("pitch ==>");
 gets(ch);
 if(ch[0]=='\0')
  ;
 else  {
  x=atoi(ch);
  *pitch=x;
 }

 printf("mode  ==>");
 gets(ch);
 if(ch[0]=='\0')
  ;
  else if(!strcmp(ch,"inflected"))
        *mode=NATURALF0;
 else if(!strcmp(ch,"monotone"))
        *mode=ROBOTICF0;

 printf("sex    ==>");
 gets(ch);
 if(ch[0]=='\0')
  ;
 else if(!strcmp(ch,"male"))
         *sex=MALE;
 else if(!strcmp(ch,"female"))
         *sex=FEMALE;

 printf("sample freq==>");
 gets(ch);

 if(ch[0]=='\0')
  ;
 else  {
    x=atoi(ch);
    *freq=x;
  }
}
```

In order to specify a phoneme stream, it is necessary to understand the rules that apply to the narrator device. First, you must become familiar with the phonetic alphabet used in the representation. This alphabet is listed in Table 8-1; it is a modification of the standard phonetic alphabet used throughout the world. This particular implementation allows the specification of any sound with two or more standard alphabetic characters. It is known as *Arpabet* from its origins with the Advanced Research Projects Agency. In translating directly into this phonetic language, you must choose symbols that indicate the various sounds that go to make up the word. This is not necessarily the same as the English spelling.

Table 8-1. Some common Arpabet symbols.

Sound	Symbol	Example
A	AE	HAT
	AO	BALK
	EY	PAID
B	B	BACK
C	K	CARL
	CH	CHOICE
D	D	DIG
E	IY	MEET
	EH	PET
F	F	FORT
G	G	GOOD
H	/H	HOLY
I	ER	DIRTY
	IH	HIT
	AY	PIE
J	J	JOIN
K	K	KEEP
L	L	LOW
M	M	MICE
N	N	NICE
	NX	PING
O	AA	POT
	UH	LOOK
	OH	HORDE
	AX	TOUT
	IX	SOLID
	OY	TOIL
	OW	KNOW
	AW	TOWER
P	P	PET
Q	K	QUIET
R	R	READ
S	S	SIT
	SH	SHOOT
T	T	TIE
	TH	THING
	DH	THE
U	AH	BUNDLE
	UW	POOL
V	V	VOTE
W	W	WASH
X	/C	YECCH
Y	Y	YELP
Z	Z	ZEAL
	ZH	MEASURE

Vowels have two qualities that can also be specified in the phonetic alphabet: *stress* and *intonation*. In any given English word, some syllables are stressed; others are not. You indicate this stress to the Narrator by placing a digit between 1 and 9 immediately after a vowel in the stressed syllable. The digit serves a dual purpose; it also specifies the intonation of

that vowel. There are basically three kinds of intonation available: *rising*, *flat*, and *falling*. The ten digits available give us varying degrees of these three. Intonation values are shown in Figure 8-1. Finally, the narrator device recognizes several common punctuation marks. These punctuation marks also indicate intonation values or pauses, of various length, between individual utterances. The recognizable punctuation marks and their values are summarized in Figure 8-2.

Figure 8-1. Some intonation values

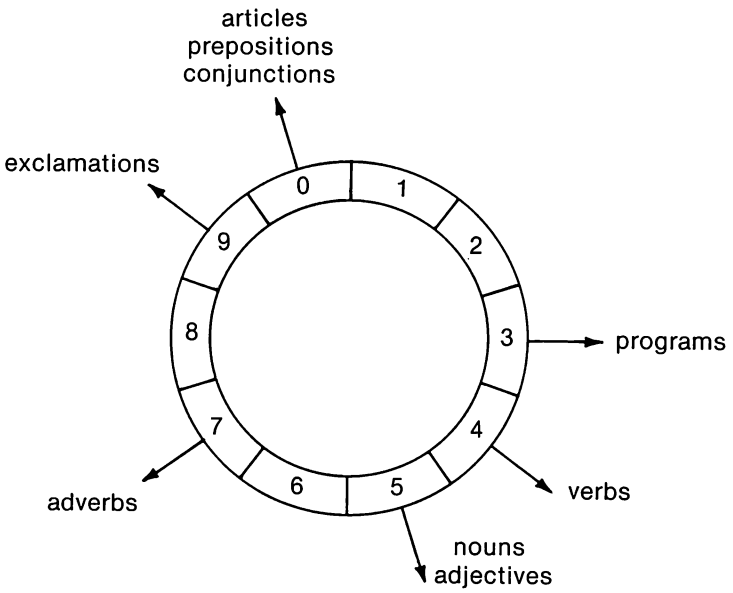


Figure 8-2. Uses of common punctuation marks

. ——→ Ends sentence or line

, ——→ Sets off a clause

? ——→ Sets information for a question

- ——→ Sets off a phrase

( ) ——→ Sets off a noun phrase

Directly passing phonetic strings to the narrator device opens up new areas for speech experimentation:

1. You can try to improve the pronunciation of special words peculiar to your application.
2. You can save the overhead of the translator library, if you just have a few words to say.
3. You can even experiment with foreign languages.

However, keep in mind that for general purpose speech synthesis, it is still more efficient to use the translator library and the narrator device together.

Summary

In this chapter we have explored the Amiga's speech synthesis capability. We have seen how this capability is split across two separate subsystems:

- The translator library
- The narrator device

Each one of these can function independently of the other.

In many important respects, the speech synthesis subsystem is no more exotic than more traditional devices, such as printers and display screens, that are found on most computers. Access on the Amiga is obtained through the message system that connects all devices defined on the Amiga. Furthermore, this message system allows you to run the narrator device in a multitasking mode; this makes it even easier to integrate with the Amiga's other features.

Programming with Disk Files

Chapter 9

The File Management System
The Notion of a File
Practical File I/O
File Maintenance Functions
Files and Multiprocessing
Disk Update Functions
Directory Maintenance
Device File Functions
Summary

In this chapter, we will explore the Amiga file system. Topics covered include:

- The directory system
- Traditional file read and write problems
- Access to the file system

We will also discuss those problems peculiar to a multiprocessing environment where processes share files.

The File Management System

Files, their creation and manipulation, are the responsibility of AmigaDOS. Both Intuition and the executive kernel depend upon this coexistent operating system to handle the details of directories and file names. It is true that the executive kernel handles a device called the TrackDisk device, which interfaces the main computer to the floppy disk drive; however, the TrackDisk is interested only in this transfer and its parameters—buffer size, location etc.

A file system is more than a mere mechanism for transferring data back and forth; it must create some structure on the disk so that data can be easily recovered. This structure includes the notion of a file as a basic storage unit, a directory that reports the contents of a disk area, and important parameters such as size, date, and access rights. Also needed are high level routines that allow you to read and write data to a file.

The file management system actually does much more than this behind the scenes. For example, it is easy to think of the directory as a display list on the screen; but in addition to giving us this inventory, it also:

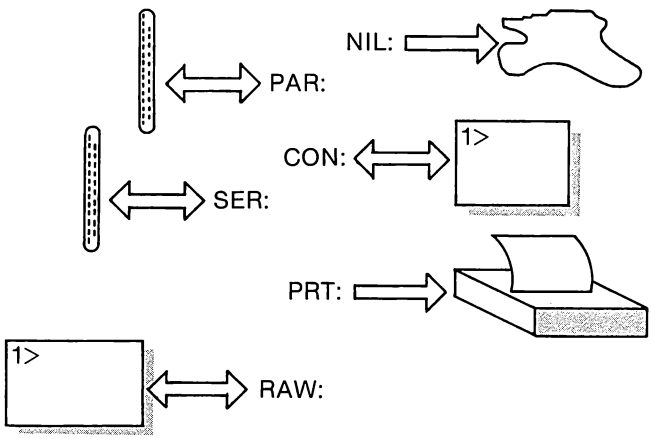
- Keeps track of the locations of each file on the disk, so that a file can be found when you need to access it

- Notes the size of the file and the location of its extensions
- Recognizes the type of file, and distinguishes between files and directories

Most of this information is available through one of the specialized AmigaDOS system calls.

The standard TTY-style interface is also maintained by the file management system. The display screen, the keyboard and the printer are all treated as disk files even though the executive kernel recognizes them as different devices. Additionally, the serial and parallel ports are also represented as file types. AmigaDOS has a number of functions that support input and output from devices. Figure 9-1 lists the device files configured in a typical Amiga system.

Figure 9-1. Device file identifiers



The system functions that we will be dealing with in this chapter are part of AmigaDOS. Just as with the multiprocessing examples in Chapter 4, these have been compiled using the initalization file *AStartUp.obj* and the library *amiga.lib*, rather than the more common *LStartUp.obj* and *lc.lib*. This is necessary because the standard C library—found in *lc.lib*—contains functions that have the same name as the AmigaDOS system calls; this library will take precedence if it is linked first. A complete explanation for this is found in Chapter 2. The necessary declarations are found in *libraries/dos.h* and *libraries/dosextens.h*.

The Notion of a File

Most programmers have a rough idea of what constitutes a file. At its minimum, it can be defined as a named location on an external storage medium—usually some kind of disk—where values can be placed and later retrieved. You can distinguish between a variable in memory and a disk file in a number of ways, not the least of which is the ephemeral nature of the first and the

long-lasting qualities of the second. Variables retain their values only as long as a program maintains them. Files keep their values even after a machine is turned off; these values remain until something removes them. Another distinguishing point is that a file can be shared among many applications, but a variable is usually restricted to a single program.

You use the notion of a file every time you access a computer. You use an editor to create a text file. You use the compiler and linker to create a binary object file. You may even have a database manager that creates database files. Programs that you load and run are files; you can see that this is a central notion to the programming environment.

Within AmigaDOS a file is represented by two entities. The most important of these is the *file handle*. Within an executing process that reads or writes data to a file, that file is represented by a file handle. This object is defined by the FileHandle structure. This structure is:

```
struct FileHandle {
   struct Msg        *fh_Link;
   struct MsgPort    *fh_Port;
   struct MsgPort    *fh_Type;
   LONG              fh_Buf,
                     fh_Pos,
                     fh_End,
                     fh_Funcs,
                     fh_Func2,
                     fh_Func3,
                     fh_Args,
                     fh_Arg2;
};
```

where

fh_Link, fh_Port, fh_Type link the structure to the executive kernel.

fh_Buf, fh_Pos, fh_End support internal buffering.

fh_Funcs, fh_Func2, fh_Func3 point to handler processes.

fh_Args, fh_Arg2 are arguments specific file types.

None of the fields in this structure are altered by user applications. This is not a variable whose values are set by the executing process; it is used to interact with the various system functions.

Almost as important is the *file lock*; this allows you to effectively share a file among competing and simultaneously executing processes. Like the file handle, the lock is defined by a structure variable and is manipulated primarily by system functions. The FileLock structure is as follows:

```
struct FileLock {
   BPTR              fl_Link;
   LONG              fl_Key,
                     fl_Access;
   struct MsgPort    *fl_Task;
   BPTR              fl_Volume;
};
```

where

fl_Link points to the next file lock on the linked list.

fl_Key is the number of the disk block.

fl_Access contains the access mode.

fl_Task indicates the port of the handler task.

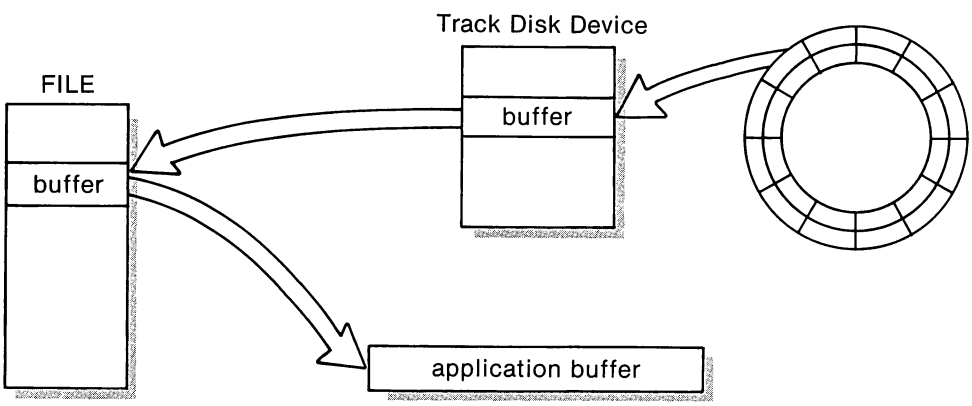
fl_Volume points to the device list.

Practical File I/O

Reading and writing from a file is the most basic operation that you can perform. Every complete operating system must supply this capability. Many programmers, however, never use the system functions built in to the operating system environment, but are content with whatever facility is offered in the language that they have chosen to implement their application. In some contexts this can be a mistake. Nothing works as well as a direct request to the system. In addition, a system call is often straightforward, while the statements offered by a programming language may be awkward, with a large overhead and strange syntax.

The C programming language provides a good illustration of the need to dip below the level of programming language to the underlying software environment. The standard file in C is defined in terms of a complex structure data type called FILE. This structure contains information about the file, information about the position of the pointer in the file, and a buffer to hold data from the file. The C functions that manipulate a file work through this data type; however, most of this buffering—indeed most of the information held in the FILE variable—is redundant. It is already available as part of the directory listing or the file header itself. Using FILE adds an unnecessary layer of overhead to the program (Figure 9-2). This redundancy may not adversely affect many non-critical programs, but an equal number will suffer from the overhead.

Figure 9-2. The redundancy of the C FILE structure



To be fair, most implementations of C—and Lattice C is no exception—offer more basic file I/O functions as part of their standard libraries. Thus, you will find functions for unbuffered file I/O, in which you supply the memory location to store data that is either coming in or going out. In many operating system environments, these functions are themselves system calls, but on most, they are not. Lattice C offers two levels of input/output statements:

1. Buffered I/O, whether formatted or not
2. A set of low-level, stream-oriented statements

The latter set views a file as a stream of bytes with no inherent structure. Even with this dual level, for many applications AmigaDOS is an attractive alternative.

Before you can do anything to a file, you must negotiate with the operating system and convince it to give you access to it. This is accomplished by the *Open()* command. This function has the format:

```
file_handle=Open(file_name,mode);
```

where

file_handle is a variable of type struct FileHandle. This identifies the file in subsequent commands; 0 indicates a failure to open the file.

file_name is a character string that contains the file name as it appears in the directory.

mode is the access mode being requested.

Mode may be one of two values:

MODE_OLDFILE opens an existing file.

MODE_NEWFILE specifies a new file.

In both cases, the file is open for reading and writing.

The *Open()* system call can be used to open certain devices as well as disk files; specifically, CON:, NIL:, and RAW: can be accessed through this command. In place of the *file_name*, put one of these device names with the format that it expects. For example:

```
f_handle=Open("CON:0/0/200/150/Window",MODE_OLDFILE)
```

This opens a new console window with the specified parameters.

Once you have finished using the file, it is necessary to relinquish control over it. This is easily accomplished by calling:

```
Close(file_handle);
```

Here, *file_handle* is a variable of type struct FileHandle, initialized by a previous call to *Open()*. AmigaDOS is not civilized enough to clean up after you. There is no mechanism for automatically closing files; you must do it explicitly or risk running out of resources. This is a particularly important

matter with a multiprocessing system, where a resource that you forget to close becomes unavailable to a simultaneously executing process. This can even lead to a deadlock situation, where both processes come to a halt because of contention over resources.

Finally, we come to the statement that enables transfer of data from disk into memory. Recall that AmigaDOS treats a file as a stream of bytes—almost as an infinitely long character string. This architecture is reflected in the input function call:

```
byte_count=Read(file_handle,buffer,buf_size)
```

where

byte_count is the number of bytes actually transferred.

file_handle is the file identifier.

buffer is a pointer to a hunk of contiguous characters.

buf_size is the number of locations in the buffer.

Both *byte_count* and *buf_size* are integer values, but remember that for AmigaDOS this means thirty-two bits. When executed, *Read()* attempts to transfer the next *buf_size* bytes in the buffer array. If it succeeds, *byte_count* is equal to *buf_size*. If there are fewer bytes left then have been requested, these are transferred and *byte_count* is set accordingly. A value of 0 in this variable indicates that the end of the file has been reached. A value of 01 shows an error condition.

The output function is complementary to the input:

```
byte_count=Write(file_handle,buffer,buf_size)
```

Here, the parameters are the same as those for the *Read()* function. You must fill the buffer with the characters or bytes that you want transferred to the file. The parameter *buf_size* indicates how many of these are to be sent over. *Write()* returns the number of bytes actually placed on the file; in most situations, *byte_count* and *buf_size* should be equal. A −1 value in this variable indicates an error condition.

These four system calls are illustrated in Listing 9-1. This program copies the contents of a file to a window on the display screen. First we access the file name through the command line arguments. Once we have this name, a call to *Open()* with a mode of MODE_OLDFILE prepares this file for reading. If the file cannot be opened, we unceremoniously stop execution with an *Exit()* call. We perform a similar service for the new window that will be our display medium.

Once we have our two files open, we prepare a buffer. Instead of the simpler process of declaring a large array of characters, we use *AllocMem()* to dynamically allocate this space. This has the felicitous property of allocating this buffer on 32-bit boundaries—something that AmigaDOS likes a great deal. A simple "do" loop empties the file into the buffer, and the buffer into the window. This loop continues until the variable *len* indicates that the end of the "form" file has been reached.

Listing 9-1. Use of Open(), Close(), Read(), and Write(). Program accepts a file, opens a window, and displays the contents of the file in that window.

```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>

#define BUFF_SIZE 256

extern struct FileHandle *Open();

main(argc,argv)
int argc;
char *argv[];
{
 struct FileHandle *fp,*sp;
 char *buffer;
 int len;

 if((fp=Open(argv[1],MODE_OLDFILE))==0)
   Exit();

 if((sp=Open("CON:10/10/500/180/Window",MODE_OLDFILE))==0)
   Exit();

 buffer=(char *)AllocMem(BUFF_SIZE,MEMF_CHIP|MEMF_CLEAR);


 do  {
      len=Read(fp,buffer,BUFF_SIZE);
      Write(sp,buffer,len);
  }
 while(len!=0);

 FreeMem(buffer,BUFF_SIZE);

 Close(sp);
 Close(fp);
}

/*********************END OF FILE************************/
```

The first priority of clean-up requires de-allocation of memory via a call to *FreeMem()*. We close both files with two separate calls to *Close()*; this only acts on a single file, thus we need one call for each open file. We do use one

undiscussed system call in this program—*Exit()*—but its operaton is straightforward and obvious.

AmigaDOS supplies one additional system function related to file input and output:

```
old=Seek(file_handle,new,from_mode)
```

This moves the file cursor to a position specified by the parameters. *Old* and *new* are both integers. *Old* marks the current position of the file cursor. *New* specifies the new position as an offset from one of three positions:

1. The beginning of the file
2. The current position of the cursor
3. The end of the file

The active position is a function of the value found in the *from_mode* parameter: OFFSET_BEGINNING, OFFSET_CURRENT, or OFFSET_END. This system function can be used in conjunction with *Read()* and *Write()* to update a file.

File Maintenance Functions

Reading and writing are not the only things you do to a file; you may need to manipulate it in other ways. AmigaDOS offers system services to support a variety of those needs.

The *Rename()* function allows you to change the name of an existing file; it has the general form:

```
boolean=Rename(old,new)
```

where

boolean is the return value—either 1 (true) or 0 (false).

old is a character string containing the current name of the file.

new is also a character string, this one with the new name.

If the name mentioned in *new* is of an existing file, the call will fail. Both *old* and *new* can be fully qualified file names; it is possible to move a file from one directory to another by taking advantage of this capability. It is not, however, possible to move a file from one volume to another.

Listing 9-2. Use of Rename(). Program accepts two file names and changes the name of the file from the first to the second.

```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
```

Listing 9-2. (cont.)

```
#include <exec/io.h>
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>


extern struct FileHandle *Open();

main(argc,argv)
int argc;
char *argv[];
{
 struct FileHandle *sp;

 if((sp=Open("CON:10/10/300/150/Window",MODE_OLDFILE))==0)
   Exit();

 Write(sp,"Renaming Files.....",20);

 if((Rename(argv[1],argv[2]))==0)  {
   Write(sp,"Files Not Renamed",20);
   Close(sp);
   Exit();
  }

 Close(sp);
}
```

Listing 9-2 displays a simple but typical use of *Rename()*. Here we accept two file names through the command line arguments—an old file name and a proposed new one. We also open a new window to display a little message that the renaming is taking place. If *Rename()* fails we report this fact and exit the program.

Another important—if drastic—task is to remove a file from the disk. You do this with a system call:

```
boolean=DeleteFile(file_name)
```

Here, *boolean* is a return value indicating the success of the action and *file_name* is a character string containing the name of the file to be removed. This system function removes either an ordinary file or a directory. The directory must be empty before it can be removed. Listing 9-3 illustrates the action of this function. Again, we display a message while the deletion is taking place; if it fails, we exit the program with an error message.

Listing 9-3. Use of DeleteFile(). Program accepts a file name from the command line and removes it from the disk.

```
#include <exec/types.h>
#include <exec/nodes.h>
```

Listing 9-3. (cont.)

```
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>


extern struct FileHandle *Open();

main(argc,argv)
int argc;
char *argv[];
{
 struct FileHandle *sp;

 if((sp=Open("CON:10/10/300/150/Window",MODE_OLDFILE))==0)
   Exit();

 Write(sp,"Deleting.......",15);

 if((DeleteFile(argv[1]))==0)  {
   Write(sp,"File Not Deleted",20);
   Close(sp);
   Exit();
  }

 Close(sp);
}
```

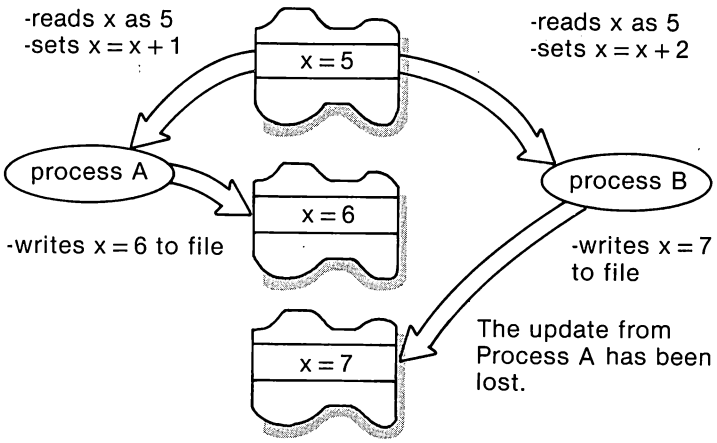
Files and Multiprocessing

One new problem faced by Amiga programmers arises from the interaction of many concurrent processes and files. On a single tasking system, only one program runs at a time. Any file that is open for reading or writing is the exclusive property of that program. On the Amiga, you can have many processes running simultaneously, and more than one process can access the same file. Under certain circumstances, this can cause problems.

One of the most common problem areas concerns files that are accessed and updated by two processes. Consider process A: it opens file *FileA* to do an update operation. Some value in the file is to be read, changed, and then written back to the same location. At the same time process B also opens *FileA*, also to do an update on the same data value. What can happen? One disastrous possibility is that process A will get the file and read the value; then, before it can change and write the value back to the file, process B will read the old data. Meanwhile A will write back its new version of the data

item followed by B's value. Whatever change process A meant to do to the file has been lost. This confusing situation—known as the "Lost Update" problem—is illustrated in Figure 9-3.

Figure 9-3. The Lost Update problem



The Lost Update is even more of a problem than most software failures. It does not happen at every file access, but depends upon a set of circumstances that is difficult to predict. Whenever more than one process is running in memory, doing different actions, it is impossible to know the order in which each process will execute. The solution to the Lost Update problem and other similar scheduling difficulties is to guarantee the order in which two processes will access the same file. You can do this by allowing one process to stake out a claim for exclusive access to the file; this is accomplished with the *file lock*.

A file lock is a simple notion. A particular process requests and is granted some level of exclusive access to the file. On a large multi-user system, the notion of a lock is a complex concept with many levels or combinations of access possible. Often a process can lock a portion of a file. AmigaDOS supports a simpler mechanism. A process can request a shared access to a given file—in this case any other process can simultaneously access it—or it can ask for exclusive access rights, barring all other processes. The mechanism for this is the system call:

```
lock_value=Lock(file_name,mode)
```

where

lock_value is the identifier for this particular file system lock.

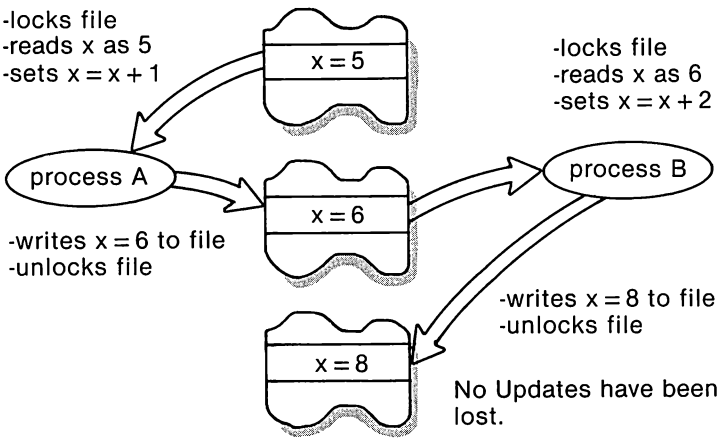
file_name is a character string that contains the name of the file as it appears in the directory.

mode indicates the access mode for the lock: ACCESS_READ creates a shared lock; ACCESS_WRITE grants exclusive access.

A *lock_value* of 0 indicates that the *Lock()* call failed. This does not necessarily indicate a problem. A failure here might indicate that some other process has put a lock on that file.

The Lost Update problem is solved by the use of file locks. Now Process A puts an exclusive lock on *FileA* until its update operation is complete. Process B has to wait to do its update, and that will be done not to the original value but to the value as altered by Process A. Figure 9-4 diagrams this situation.

Figure 9-4. The Lost Update problem solved



There is a complementary function to *Lock()* that releases a file to general use:

```
UnLock(lock_value)
```

Here *lock_value* is an identifier from a previously executed *Lock()* function. This function does not return a value.

Disk Update Functions

One kind of update we might wish to perform on a file is to write into its comment field. This field may be filled with any desired text and is meant to serve as additional information about the file. This comment field can be displayed by the *List* command. Access to this part of the file is through an AmigaDOS function:

```
boolean=SetComment(file_name,comment_field)
```

where

boolean indicates the success or failure of the call.

file_name is a character string containing the name of a file as it appears in a directory.

comment_field is a pointer to a character string that contains the text of the comment.

This comment field may be up to eighty characters long.

Listing 9-4. use of SetComment() to attach a comment to a file.

```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>



main(argc,argv)
int argc;
char *argv[];
{
 struct FileLock *lock,*Lock();
 struct FileHandle *sp,*Input();
 char buffer[80],fname[70];

 sp=Input();

 if((lock=Lock(argv[1],ACCESS_WRITE))==0)  {
   printf("\nCan't open file\n");
   UnLock(lock);
   Exit();
  }


 printf("Comment: ");
 get_string(sp,buffer,80);


 if((SetComment(argv[1],buffer))==0)
    switch(IoErr())  {
      case ERROR_COMMENT_TOO_BIG:    printf("Use a shorter comment\n");
                                     break;
      case ERROR_DEVICE_NOT_MOUNTED: printf("Device not mounted\n");
                                     break;
      case ERROR_WRITE_PROTECTED:
```

Listing 9-4. (cont.)

```
            printf("Diskette is write protected\n");
                                        break;
       case ERROR_NO_DISK:              printf("No diskette in the drive\n");
                                        break;
      }

  UnLock(lock);

}

get_string(fp,buffer,maxlen)
struct FileHandle *fp;
char *buffer;
int maxlen;
{
 int len;

 len=Read(fp,buffer,maxlen);
 buffer+=len+1;
 *buffer='\0';
}
```

Listing 9-4 contains a program that allows the user to set the comment field in a specific file. The file name is entered through the command line arguments. The first thing we do with this file is try to put a lock on it; if the lock fails, we exit with an error message. If we are successful in locking the file, we prompt the user for the comment string; this is then used in a call to *SetComment()*. If the call fails we invoke a new system function *IoErr()* for a more specific error message. Finally we call *UnLock()* to release the file. It is necessary to use the home grown input routine *get_string()*, because we are using the *amiga.lib* library and not *lc.lib*. Common amenities like *scanf()* are not available.

IoErr() takes no parameters but returns an integer value that represents a global error message. This numeric value is associated with a particular error message. No global error message array—such as you find in the C standard library—is available. It is the responsibility of the application to create such an error message. Each error number is associated with a condition, using a *#define* statement. These statements are found in *libraries/dos.h*. In our example program, we use a *switch* statement to perform this error reporting function.

Before you do anything to a disk by way of reading, writing, or updating, it is important that you have some way of judging that disk's key parameters. Things like the size of the disk, its format, and other operational parameters are necessary for certain kinds of access. This information is stored in a special variable of type struct InfoData. The form of this structure is:

```
struct InfoData {
   LONG     id_NumSoftErrors,
            id_UnitNumber,
            id_DiskState,
            id_NumBlocks,
            id_NumBlocksUsed,
            id_BytesPerBlock,
            id_DiskType;
   BSTR     id_VolumeNode;
   LONG     id_InUse;
};
```

where

id_NumSoftErrors indicates the number of errors found on the disk.

id_UnitNumber indicates the unit of the disk.

id_DiskState indicates the current condition of the disk.

id_NumBlocks counts the number of blocks on the disk.

id_NumBlocksUsed is the number of blocks currently in use.

id_BytesPerBlock shows the number of bytes contained in a block.

id_DiskType contains the type code.

id_VolumeNode points to a BCPL string containing the volume name.

id_InUse is a flag value.

The variable itself is filled by a call to:

```
boolean=Info(lock_value,info_variable)
```

where

boolean indicates the success or failure of the call.

lock_value is a lock identifier from a call to Lock( ).

info_variable is a pointer to a variable of type struct InfoData.

This system function returns information on the disk as a whole and not on specific files or directories in that disk. The variable *lock_value* can refer to a disk or any file on that disk. The information is returned through the InfoData structure.

Listing 9-5. Use of Lock( ) and Info( ) to accept the name of a disk volume and return interesting parameters relating to it.

```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
```

Listing 9-5. (cont.)

```
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>



main(argc,argv)
int argc;
char *argv[];
{
 struct FileLock *lock,*Lock();

 struct InfoData *i_data;
 if((lock=(struct FileLock *)
   AllocMem(sizeof(struct FileLock),MEMF_CHIP|MEMF_CLEAR))==0)
   Exit();

 if((i_data=(struct InfoData *)
   AllocMem(sizeof(struct InfoData),MEMF_CHIP|MEMF_CLEAR))==0)
   Exit();

 if((lock=Lock(argv[1],ACCESS_READ))==0)
   Exit();

 if((Info(lock,i_data))==0)
   Exit();

 printf("Soft errors===>%ld\n",i_data->id_NumSoftErrors);
 printf("Unit number===>%ld\n",i_data->id_UnitNumber);
 printf("Total blocks==>%ld\n",i_data->id_NumBlocks);
 printf("Blocks in use=>%ld\n",i_data->id_NumBlocksUsed);
 printf("Blocks
free===>%ld\n",i_data->id_NumBlocks-i_data->id_NumBlocksUsed);

 UnLock(lock);

}
```

Listing 9-5 illustrates a program that accesses information about a specific disk. We accept a name through the command line arguments. This can be either a file, a directory, or simply a disk identifier—either *dfnn* or a volume label. The program creates a lock pointer variable by a call to *AllocMem()*. This is desirable because AmigaDOS requires variables that are aligned with 32-bit values and using this function guarantees this alignment. Similarly, we create the variable *i_data*. Then an attempt is made to create a lock using the entered file name. If the attempt succeeds, we call *Info()*, passing it *lock* and *i_data*. If this, in turn, succeeds, we print out some interesting information about the disk. In operation, this program is similar to the CLI command *Info.Cleanup* and exit requires a call to *UnLock()*.

Directory Maintenance

Disk directories play a large role in maintaining the file system. They report the contents of individual disks, tell important things about the individual files on the disk, and even report idiosyncratic information through the file comment field. AmigaDOS offers a variety of system calls to deal with this very important software object.

A vital element in accessing a directory is the FileInfoBlock structure. The directory functions pass information back about files and directories through variables of this type. The structure contains a field for every important parameter:

```
struct FileInfoBlock {
   LONG   fib_Diskey,
          fib_DirEntryType;
   BYTE   fib_FileName[108];
   LONG   fib_EntryType,
          fib_Size,
          fib_NumBlocks;
   struct DateStamp     fib_Date;
   char                 fib_Comment[116];
};
```

where

fib_DirEntryType indicates the type of entry:
—a value < 0 indicates a file;
—a value > 0, a directory.

fib_FileName is a character string containing the name of a file or directory.

fib_Protection contains the protection code.

fib_Size contains the number of bytes in the file.

fib_NumBlocks reports on the number of blocks in the file.

fib_Date is the date last changed.

fib_Comment is the comment field.

fib_Diskey and **fib_EntryType** are not for user applications.

Variables of this type are passed to the directory and file functions, which in turn fill the fields with current data.

To gather information about a file or directory, you can call:

```
boolean=Examine(lock_value,fblock_ptr)
```

where

boolean indicates the success or failure of the call.

lock_value is a lock identifier from a previous call to Lock( ).

fblock_ptr is a pointer to a variable of type FileInfoBlock.

This fills the specified *FileInfoBlock* variable with the current values for the file, or the directory associated with the *lock* value. Listing 9-6 indicates how this function can be used to make a report. The program accepts the name of the disk object through the command line arguments, a lock variable and a *FileInfoBlock* variable. *AllocMem* is used to ensure the proper memory word alignment. An attempt is made to create a lock for this object—ACCESS_READ is acceptable because we are not doing an update, only getting information. A call to *Examine()* fills the variable and then displays some interesting values on the screen. *UnLock()* completes the program.

Listing 9-6. Use of Lock() and Examine() to accept the name of a file or directory and display interesting information about it.

```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>



main(argc,argv)
int argc;
char *argv[];
{
 struct FileLock *lock,*Lock();
 struct FileInfoBlock *f_info;

 if((lock=(struct FileLock *)
   AllocMem(sizeof(struct FileLock),MEMF_CHIP|MEMF_CLEAR))==0)
   Exit();

 if((f_info=(struct FileInfoBlock *)
   AllocMem(sizeof(struct FileInfoBlock),MEMF_CHIP|MEMF_CLEAR))==0)
   Exit();

 if((lock=Lock(argv[1],ACCESS_READ))==0)
   Exit();

 if((Examine(lock,f_info))==0)
   Exit();

 if(f_info->fib_DirEntryType<0)
    printf("Type====>File\n");
 else
    printf("Type====>Directory\n");
 printf("Name====>%s\n",f_info->fib_FileName);
 printf("Size====>%ld\n",f_info->fib_Size);
```

Listing 9-6. (cont.)

```
 printf("Blocks==>%ld\n",f_info->fib_NumBlocks);
 printf("Note====>%s\n",f_info->fib_Comment);

 UnLock(lock);

}
```

Examine() releases information on a single file or a directory; however, we also want to go to a particular directory and display information for all the files in that directory. We cannot do this with *Examine()* alone, but also need to use:

```
boolean=ExNext(lock_value,fblock_ptr)
```

The parameters here take on the same values as *Examine()*. This system function returns information on the next file in the directory. *ExNext()* is used in conjunction with *Examine()* to read through a directory. The following set of procedures yields this directory listing:

1. Use *Examine()* to gather information about the directory.
2. Use repeated calls to *ExNext()* to get data on the subsequent files in the directory.

It is necessary to create a loop to repeatedly execute *ExNext*, until it finally returns an error condition. Once this has occurred, a call to *IoErr()* verifies that the current condition signals the end of the directory and not a true error. This algorithm is illustrated in Listing 9-7. This program is similar to Program 9-6, except that here we have a *while* loop that continues until *ExNext()* returns 0. The display function has been imported to a function to make the program flow more structured.

Listing 9-7. Use of Lock(), Examine(), ExNext(), IoErr(), and UnLock(). The program accepts the name of a directory and displays information about the file it contains.

```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>
```

Listing 9-7. (cont.)

```
main(argc,argv)
int argc;
char *argv[];
{
 struct FileLock *lock,*Lock();
 struct FileInfoBlock *f_info;

 if((lock=(struct FileLock *)
   AllocMem(sizeof(struct FileLock),MEMF_CHIP|MEMF_CLEAR))==0)
   Exit();

 if((f_info=(struct FileInfoBlock *)
   AllocMem(sizeof(struct FileInfoBlock),MEMF_CHIP|MEMF_CLEAR))==0)
   Exit();

 if((lock=Lock(argv[1],ACCESS_READ))==0)
   Exit();

 if((Examine(lock,f_info))==0)
   Exit();

 spill_the_beans(f_info);

 while ((ExNext(lock,f_info))!=0)
   spill_the_beans(f_info);

 if(IoErr()==ERROR_NO_MORE_ENTRIES)
   printf("\nEnd of directory==================\n");
 else
   printf("\nError reading directory===========\n");

 UnLock(lock);

}
spill_the_beans(info)
struct FileInfoBlock *info;
{
 printf("\n\nName====>%s\n",info->fib_FileName);
 printf("Size====>%ld\n",info->fib_Size);
 printf("Blocks==>%ld\n",info->fib_NumBlocks);
 printf("Note====>%s\n",info->fib_Comment);
}
```

AmigaDOS offers some important capabilities in addition to those already discussed—for example:

```
lock_value=CreateDir(direct_name)
```

This takes the name of a new directory and creates that directory on the disk. A lock is automatically opened and returned by this function. A 0 is returned if the proposed name is the same as an existing directory.

Listing 9-8. Use of CreateDir() to create a new directory.

```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>


main(argc,argv)
int argc;
char *argv[];
{
 struct FileLock *lock,*CreateDir();


 if((lock=CreateDir(argv[1]))==0)
    Exit();

 UnLock(lock);

}
```

Listing 9-8 contains a simple example. Listing 9-9 illustrates another system call:

```
old=CurrentDir(new)
```

Here *old* and *new* are lock values. This function changes the current working directory to the directory associated with *new*; it returns the current directory value before the change is made.

AmigaDOS offers one last directory function:

```
boolean=SetProtection(file_name,mask_value)
```

Listing 9-9. Use of CreateDir() and CurrentDir() to create a new directory and make it the current directory.

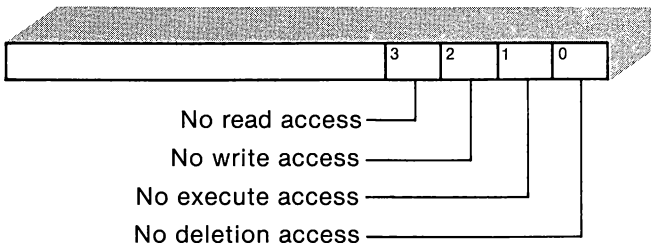
```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
#include <exec/memory.h>
```

Listing 9-9. (cont.)

```
#include <libraries/dos.h>
#include <libraries/dosextens.h>


main(argc,argv)
int argc;
char *argv[];
{
 struct FileLock *lock,*last,*CreateDir(),*CurrentDir();


 if((lock=CreateDir(argv[1]))==0)
    Exit();

 if((last=CurrentDir(lock))==0)
    Exit();

 UnLock(lock);
 UnLock(last);


}
```

This function sets the protection attributes of the file. Here *file_name* is a character string containing the file name, and *Mask_value* is a bit mask containing the protection code. Figure 9-5 indicates values for this mask. *Read*, *write*, *execute*, and *delete* modes are all set by this function.

Figure 9-5. SetProtection() bit mask values



Device File Functions

Our final example program deals not with disk files, but with device files—input/output peripherals treated as if they were files. It is economical and

productive to have a common interface to the outside world; this is the motivation for using the file metaphor so widely in the Amiga and most other computer systems. However, there are activities that are peculiar to devices, particularly interactive devices such as the keyboard and display screen. Fortunately, AmigaDOS recognizes these peculiarities and supplies functions that address them.

The first set of device file functions is a pair of system calls that lets you get a handle on the standard input and output that is automatically attached to a process when it starts executing.

```
file_handle_in=Input()
```

returns the file handle of *stdin*.

```
file_handle_out=OutPut()
```

does the same for *stdout*. These functions allow you to use these devices with the other file manipulation system functions, to create reasonable output displays and to take in values in a straightforward manner.

The last function we will discuss is also very useful in creating reasonable input routines.

```
boolean=WaitForChar(file_handle,timer)
```

puts a time limit on input from the keyboard or any other interactive device. It returns true (−1) if a character is entered before the time specified in *timer* is used up; otherwise, a value of false is returned. The parameter timer is measured in microseconds.

Listing 9-10 illustrates the use of *Input()* and *WaitForChar()*. We declare *sp*, a pointer to a FileHandle structure and a *buffer*, a pointer to a character. Using *AllocMem()* we allocate the buffer space; using *Input()*, we set *sp* equal to our standard input file. A call to *WaitForChar()* sets up our measurement and a subsequent call to *Read()* puts the characters into our buffer. If we wait too long and use up our time, a message is printed and the program is exited; otherwise we print out the character string that we entered.

Listing 9-10. Use of Input(), WaitForChar(), and Read() to wait for a character, then read from the keyboard.

```
#include <exec/types.h>
#include <exec/nodes.h>
#include <exec/lists.h>
#include <exec/libraries.h>
#include <exec/ports.h>
#include <exec/interrupts.h>
#include <exec/io.h>
#include <exec/memory.h>
#include <libraries/dos.h>
#include <libraries/dosextens.h>
```

Listing 9-10. (cont.)

```
#define SEC 1000000

main()
{
 struct FileHandle *sp,*Input();
 int len,result;
 char *buffer,*AllocMem();

 if((buffer=AllocMem(128,MEMF_CLEAR))==0)  {
   printf("Not enough memory for a buffer\n");
   Exit();
  }

 sp=Input();


 result=WaitForChar(sp,SEC);

 if(result==0)  {
      printf("\nTimeout\n");
      Exit();
     }

 len=Read(sp,buffer,128);
 *(buffer+(len+1))='\0';

 printf("==>%s\n",buffer);

}
```

Summary

In this chapter we have covered the AmigaDOS file management system. We have seen how files are defined and accessed. We have dealt with the notion of file locks and how they help manipulate files in a multiprocessing environment.

We have discussed directories and the functions that report on their status and list their files. AmigaDOS also supplies functions that create new directories and change the current working directory.

Finally, we have dealt with the difference between disk files and device files. We have seen how to get access to the standard input and output devices and use them in programs to create interesting input and output screens. We have explored the uses of the *WaitForChar()* function and how it can be used to time input requests.

Index

A

AddBob( ) function to add Bobs to the GELs linked list, 252
AddGadget( ) function to assign a system gadget to a window, 66, 75
AddPort( ) function to add ports to the system, 124
AddSprite( ) function to add VSprite variables to the GELs linked list, 239
Advanced Research Projects Agency, 343
Alerts, 95–97
ALINK linker for the C compiler on the Amiga, 15
  files accepted by the, 20
  invoking the, 21–24
  passes of the, 20–21
  warning messages of the, 21
Amiga
  creating sound on the, 271–74
  hardware architecture of the, 4
  overview of the, 3–4
  programming environment of the, 9–27
  software architecture of the, 5–6
AmigaDOS operating system, 115–44
  accessed through AStartUp.obj, 24, 350
  calling the, 128–29
  console treated as a kind of file by the, 104
AmigaDOS operating system—cont
  control of the file management and multiprocessing systems through, 117
  device file to activate the console device, 104
  for file management and multiprocessing support, 5, 12, 13, 349
  process definition, 127
  system functions for file management, 349–72
amiga.lib AmigaDOS functions library, 24
  AmigaDOS functions called by linking the source code to the, 129
  used to compile system functions, 350
Amplitude of a sound wave, 268
Analog quantities of sound translated to digital representations used by the computer, 268–69
Area fill of a graphic
  program using flood fill for the, 197–98
  program using outlining for the, 193–95
  program using RectFill( ) function with a pattern for the, 200–201

Area fill of a graphic—cont
program using ROM kernel graphics routines for the, 191-93, 200-201, 202-5
program using SetRast( ) function for the, 202-5
system calls for the, 189-91
AreaInfo structure to set up a buffer of information about a figure, 191
AreaMove( ) and AreaDraw( ) functions to fill polygons, 190-91, 193
Arpabet of sounds with two or more standard alphabetic characters, 343-44
Artificial speech, 3, 309-46
program using the set_to_talk( ) function for unlimited number of spoken lines for, 320-22
program using the speech synthesis subsystem to convert a single line to phonemes, then speak it, 323-25
program using the speech synthesis subsystem to convert an unlimited number of lines and speak them, 326-28
program using the translator library and narrator device to produce phonemes for, 317-19
ASCII characters used with the console device, 104
Audio device, 271-72
accessing the, 274-97
commands, 276-78
controlling the, 278-97
frequency in rendering speech sounds, 317
opening the, 274-75
program to finish executing a sound with the, 279-80
program to specify the number of cycles for the, 277-78
program to start a note and vary its loudness via messages sent to the, 290-92
program to start a note and vary its period via messages sent to the, 287-89
program to use a single channel of the, 284-86
Audio device—cont
program to use a square wave with the, 281-82, 284
program to use a triangular wave with the, 282-84
program to vary the loudness of a note using an array for the, 292-95
Audio system. *See also* Sound
circuitry, Amiga's quality, 3
four digital to analog converters for versatility in creating sounds with the, 4, 267, 271, 311
AUDIONAME global value, 275
AutoRequest( ) function to create and install a boolean requester, 93-95

B

Bit planes
allocated for a screen, 52, 163
Bobs images created through overlapping, 251-52
Blitter device
to move and combine data in memory, 4
ROM kernel graphics commands that directly interact with the, 182
Blitter objects (Bobs), 236
added and removed, from the GELs animation list, 252
compared with functions of the VSprite, 251
created with a struct Bob variable and VSprite variable, 251
program illustrating the SAVEBACK feature, 257-60
program to create a simple, 253-56
program to mix VSprites and, 260-64
Bob variable, 251
Book, organization of the, 6-7
Boolean gadgets, 65, 71, 178, 181
Boolean requester, 93
Borders by Intuition graphics system data structures for, 149-150
program to create several linked, 153-55

Borders by Intuition graphics system—cont
program to create simple, 151–53
types of, 148–49
Buffer
for information about a figure created by AreaInfo structure, 191
to receive characters from a gadget, 73

C

C compiler, functions of the, 15–16
C language
function calls, 6
standard file definition in the, 352–53
structure data types, 14–15
system access through, 14–25
system programming, 6
ClearMenuStrip( ) function, 81
CLI command interpreter
calling processes from the, 129–31
to start independent executing processes, 132
Close( ) AmigaDOS function call
to relinquish control over a file, 353, 355
to shut down the console, 104
Close Gadget, 66, 69
CloseDevice( ) system function to remove an audio device to a program, 271
CloseLibrary( ) function to allow the operating system to reclaim memory used by the translator library, 313
Color and the sprites, 219–220
Color register(s) in the Amiga, 4
addresses of, 52
associated with VSprites, 238
identifier and map for, 219–20
each pixel assigned a value that points to a, 219
Command file generated by ALINK, 21–22
Comments for a file, 360–62
Compilation of individual function files then combined by the linker, 62–63, 112
Compiler. *See* C compiler *and* Lattice C compiler
Composite gadget, 177
Console device, 103–6
Copper general purpose processor to control the graphics system, 4
ROM kernel graphics commands that directly interact with the, 182
Coprocessors in the Amiga to handle specialized tasks, 4
CreateDir( ) function to create a directory and a file lock, 368–70
CreatePort( ) function to generate a new port, 124
CreateProc( ) AmigaDOS function to return a process_id and start the process, 133, 134–43
Cross-reference table of symbols and references in the file, 23
CurrentDir( ) function to make a directory the current one, 369–70
Custom (application specific) gadgets, 70–76
Customized screen(s) in Intuition, 33–34, 39
positioning the, 51–52
program for creating a high-resolution window and a low-resolution window in two overlapping, 56–57
program for creating a window in a, 48–51
program for creating a window with custom colors in a, 52
program for creating two overlapping high-resolution, 53–56
Cycles of a sound, 272, 273, 277–78

D

Data transfer directly from memory and diskette, 4
Data types
C language structure, 14–15
specialized Amiga, 25–26
structure, 70
DateStamp( ) AmigaDOS system call, 129
Datestamp structure, 128
Delay( ) AmigaDOS system call to add a delay in a program, 130

DeleteFile( ) function to delete a file or directory, 357–58
Depth Arrangement Gadget, 219
Depth Gadget, 66, 69
Device drivers for the Amiga, 4
Device file
  functions, 370–72
  identifiers, 350
Digital representations of sound used by the Amiga, 268–69
Digital to analog converters for versatility in creating sounds, 4, 267, 271, 311
Direct Memory Access (DMA)
  channels, eight special purpose, 213
  coprocessors, 4
Directory
  functions of the disk, 349–50
  maintenance, 365–70
  program to display information about a, 366–68
Disk
  files, programming with, 349–72
  update functions, 360–64
  volume parameters, program to return the, 363–64
DisplayAlert( ) function, 96
Drag Gadget, 66, 69
Draw( ) function to sketch a line in the color set by FgPen, 184, 188
DrawBorder( ) Intuition function to create a border, 148
DrawImage( ) Intuition function to generate a drawing, 148, 165
Drawing pens defined in the RastPort structure, 183
Drawing program, example of a, 207–10

E

Error checking not complete in the example programs, 7–8, 112–14
Examine( ) function to display information about a file or directory, 366–68
Example programs in this book, 7–8
Executable file developed through the linker as the third stage in program development, 15
Exec kernel. *See* ROM kernel graphics commands
Execute( ) AmigaDOS system call for simple multiprocessing, 129–31
Executive kernel operating environment, 5, 12, 13–14
  console device opened directly using the, 104
  message passing system of the, 119–22, 123–27, 319
  ports and messages manipulated by the, 124
  software support for process creation supplied by, 127
  TrackDisk device handled by the, 349
ExNext( ) function to retrieve data about subsequent files, 367–68

F

FgPen function
  colors rendered by the, 183–84, 189
  with PolyDraw to draw a polygon, 186–88
File(s)
  changing the name of a, 356–57
  comments for a, 360–62
  cursor, moving the, 356
  definition of a, 350–52
  deleting a directory or a, 357–58
  device, functions of the, 370–72
  explicit closing of each, 353
  handle, 351
  I/O, 352–56
  locks to share files among processes, 351, 359–60, 362, 364, 368
  maintenance functions, 356–58
  multiprocessing and, 358–60
  program to display information about a, 366–68
File management
  through AmigaDOS, 5, 12, 13, 349
  system, 349–50
FileHandle structure, 353
FileInfoBlock structure, 365–66
FileLock structure, 351–52
Flags, IDCMP, 83, 98–103
Flood( ) function to draw a figure in outline, then fill it, 195–98
Font, user-customized, 148

Formants as frequencies to produce sounds of human speech, 311
Frequency
audio device, 317
of a sound wave, 268, 272, 273-74

G

Gadget(s)
application-specific (custom), 70-76
controlling the interaction of individual, 72
flags for, 67-68, 100-101
graphics used with, 167-76
library, 176-82
program to create a window containing the system, 68-69
program to develop access routines for, 178-81
as specialized control objects in Intuition windows, 31
system, 66-70
types of, 65-66
GelsInfo structure variable, 236, 239, 244, 248
Get_mouse( ) function to trap events within a window, 206-10
GetMsg( ) function
to remove a process from a queue, 136
to retrieve a message from a port, 125, 126
Get_prop( ) function to create a proportional gadget, 181
Get_string( ) function to create a three way gadget setup, 181
Graphic Elements (GELs) subsystem
displaying a list of the system objects of the, 239-40
list, adding or removing Bobs on the, 252
list, program example of multiple VSprites managed by one, 248-51
virtual sprites (VSprites) and blitter objects (Bobs) as the two basic units of the, 236
Graphics
commands, ROM kernel, 182-201
gadgets used with, 167-76
Intuition to prepare, 145-210
Graphics—cont
object movements controlled by sprite processors, 4
as one of the features of the Amiga, 3
output from Intuition, three types of, 148
routines for displaying values and pictures, 103
system controlled by the Copper processor, 4
Graphics kernel functions for line drawing, 184-88
Graphics primitives, creating an image directly using, 103
"Guru Meditation" box, 96

H

Hardware
accessing resources of the, traditional method of, 11-12
architecture of the Amiga, 4
High-resolution mode
screens, 51, 53
screens using very, 57
Hold-and-modify (HAM) mode, 51
Hot spot, 216-17
Human speech, generation of, 311-12

I

Iconic interface, 134
IDCMP (Direct Communications Message Ports) facility for communications, 83, 98-103
flags of the, 98, 100-101
program to communicate with an open window using, 102-3
Images as output from Intuition graphics system, 148
data structures for, 162-63
definition of, 161
program to create several, 165-67
program to create simple, 163-65
Info( ) function to return disk volume parameters, 363-64
InfoData variable, 362-63
Input
device, 97
event, 97-98
stream, 97-98

Input( ) function to wait for a character to read from the keyboard, 371
Input/output (i/o)
from Boolean gadgets handled by the get_flag( ) function, 178
operations stored in Intuition files, 106–12
Integer gadgets, 66, 75–76
Interlace mode (interlaced screen), 51, 57–61
Intonation
of punctuation marks by the narrator device, 345
three kinds of, 345
of vowels handled by the Narrator, 344–45
of words affected by the translate( ) function, 315
IntuiMessage object, 98, 99–100
IntuiText for graphics output from Intuition, 148
data structures of the, 155–57
measuring the length of a display in pixels with, 157
program to create a simple structure with, 157–58
program to create linked structures with, 158–61
Intuition, 29–114
drawing or preparing graphics with, 145–210
file to open, 62–63
library, building an, 106–12
as the primary user interface, 5, 12–13
resources of, 31
as a run-time library, 32
IntuitionBase variable, 32
I/O redirection
Amiga's simplification of, 12
in the terminal-like user interface of the Amiga, 3
IOAudio structure, 273, 274–76, 278, 284
Ioerr( ) function to check for file errors, 367–68
ItemAddress( ) function to capture a MenuItem structure's address, 81

L

Lattice C compiler
data element sizes for the, 26
passes of the, 16–20
phases of the, 16–19
starting a compile with the, 16–17
toggles for the, list of, 17–19
two levels of input/output statements offered by the, 353
lc.lib standard library of routines, 24
Libraries
Intuition, 106–12
linked to programs with the Amiga, 24
loaded along with programs, not added to them, 32
program to test functions of, 111–12
Lines, graphics kernel functions to draw, 184–88
Linker. *See* ALINK linker for the C compiler on the Amiga
LoadSeg( ) AmigaDOS function to load object file into free memory locations, 132, 134–43
Lock( ) function
to display information about a file or directory, 366–68
to return disk volume parameters, 363–64
"Lost Update" problem, 358–60
Loudness (amplitude) of a sound, 272–74, 290–95

M

Makebar( ) function to draw a series of lines in one color, 184
Map of the executable module, 22–23
Mapleft and mapright bit maps, 301
MC68000 (Motorola) processor in the Amiga, 4
assembler for the, 5
Memory
Amiga's addressable, 4
chip, 8
co-resident programs loaded at the other end of the computer's address system from the main program in, 119
processes in, 119

Memory—cont
resource freed by programmer's code after a library, screen, or window is no longer needed, 112–13, 132–33, 226, 355
tasking system to manage a process in, 127–28
Menu(s)
creating a, 81–92
defining a, 77–81
file containing the setup for, 210
flags for a, 80–81, 101
positioning a, 77–78
program to create a, 84–86
program to create, in two windows, 89–92
program to create two, in one window 86–89
setting up a, 76–92
Menu strip, 83
MenuItem structure, initializing a, 78–79
Message(s)
facility, Narrator accessed using the, 316
header, 127
passing system between processes, 119–22, 123–27, 319
system to handle communications between an application and the audio device, 271
Mode values of the set_params( ) function for varied speech parameters, 332–35
ModifyIDCMP( ) system function to prepare an open window to report on mouse and menu activity, 208
Modular programming, 62–65
Monaural sound possible with the Amiga, 271
Mouse
cursor, sprite 0 as the, 213, 214, 216–19
as the main access channel in Intuition, 31
to select menu options, 77
Mouth_rb structure to send messages to the Narrator without waiting for their completion, 325
Move( ) graphics kernel function to reposition the drawing cursor, 184, 188
MoveSprite( ) function call to move a sprite on the screen, 226
Multiprocessing
design of applications affected by, 3–4
files and, 358–60
operating system of the Amiga, 3
Multitasking, 3, 13
advantages of, 117–18
artificial speech programs using, 322–25

N

Narrator device to produce speech, 312
accessed through the message facility, 316
advantages of directly passing phonetic strings to the, 346
Arpabet sounds used by the, 343–44
background mode can be used to run processes of the, 315, 325–26
fields of the, 316–17
intonation of vowels and punctuation marks by the, 344–45
phonetic alphabet used by, 343
program using the direct input of phonetics with the, 339–43
program using pitch, mode, and sex values to the set_params function to expand the range of speech parameters for the, 322–35
program using the set_params( ) function and sampling frequency for the, 335–43
program using the set_params( ) function to set speech parameters for the, 328–31
program using the translator library and the, 317–19
varying the parameters sent to the, 328–46
NewScreen structure to specify screen parameters, 48
NewWindow structure to specify window parameters, 35–36, 38–39

NewWindow structure to specify window parameters—cont
IDCMPFlags field of the, 70

O

Object file
compiled as the second stage in program development, 15
as an image of the memory when the program runs, 118
Object modular disassemble (OMD) utility, 19-20
OnMenu( ) and OffMenu( ) functions to turn menu items on and off without removing them, 81
Open( ) AmigaDOS function call
to open devices and disk files, 353
to prepare a file for reading, 354-55
to set up and start the console, 104
OpenDevice( ) system function to attach an audio device to a program, 271, 284
OpenLibrary( ) function to open the translator library, 313
OpenWindow( ) function to create a window, 35-38
Operating system(s) of the Amiga, three interacting, 3, 5, 12-14

P

Pattern fill, 199-201
Period of a sound wave, 272, 273-74, 286, 289, 295-97
Phonemes
as linguistic sounds, 312
streams of, 343
Pitch values of the set_params( ) function for varied speech parameters, 332-35
Pixels (picture elements)
image to create a display by specifying the color information in, 161-62
length of an IntuiText display measured in, 157
measurements of the, 214
transparent, 219
Pixels (picture elements)—cont
as the unit for measuring window positions, 35-36, 52
Port(s)
address, 124
associated with each process, 120
relationship of messages and, 123-26
reply, 122, 124
Preprocessor command execution, 16
PrintText( ) Intuition function to generate a character display, 148
Process
child, 136, 138
defined, 119
parent, 136, 138
program to create a complex, 139-41
program to create a simple, 134-36, 137-38
program to create two, 141-43
structure definition of an AmigaDOS, 127
Process control, 115-44
Program, example of a complete, 113-14
Programming environment, 9-27
Intuition as the most difficult Amiga, 31
software components of the, 11-14
Programming style notes for example programs, 7-8, 112-14
Proportional gadgets, 66, 170-76, 181
Punctuation marks recognized by the narrator device, 345
PutMsg( ) function to send an initialized message structure to a particular port, 125-26

Q

Queue for a process
CreateProc( ) AmigaDOS function to insert a, 133
removing a process from the, 136

R

RastPort structure, 183-84, 199
Read( ) function

Read( ) function—cont
to read a character from the keyboard, 371–72
to transfer bytes in the buffer array, 354–55
RectFill( ) function to fill a figure with a pattern, 200–201
RefreshGadget( ) function, 75
RemoveGadget( ) function to delete gadgets in an open window, 75
RemIBob( ) system call to remove Bobs from the GELs system linked list, 252
RemPort( ) function to remove ports from the system, 124
RemVSprite( ) system call to remove virtual sprites from the GELs system linked list, 239
Rename( ) function to change the name of an existing file, 356–57
ReplyMsg( ) system call to return the message structure to the port, 125–26
Requester for entering values, 92–95, 101
ROM kernel graphics commands, 182–201

S

Sampling an analog waveform , 269–70
frequency for, 317
interval for, 273
Sawtooth waveform, 273, 276–78
Screen(s). *See also* Customized screen(s) in Intuition
as the background for windows, 33
high-resolution, 51, 53
as the main visual object in Intuition, 31
RastPort opened for each Intuition, 183
support file stored as a separate function for Intuition, 63–64
two kinds of Intuition, 33
ScrollRaster( ) function, 205–7
Sentences, Translate( ) function converts all strings to, 315
SetAPen( ) function with Draw( ) function to produce multicolored lines, 184
SetMenuStrip( ) function to associate a menu with a window, 81–82
Set_params( ) function to set the parameters of speech, 328–39
SetPointer( ) function to alter the shape of the mouse cursor, 216–19
SetProtection( ) bit mask values, 370
SetRast( ) function to set the raster display to the pen color, 202–5
Set_to_talk( ) function to allow unlimited spoken lines, program using the, 320–22
Sex values of the set_params( ) function for varied speech parameters, 332–35
SimpleSprite structure, 220–226
Sin( ) function to fill an array to produce a sine curve, 273
Size of compiled code, message indicating the, 19
Sizing gadget, 66, 69, 70
Software components of the programming environment, 11–14
Sound, 265–308
Amiga produces stereo, 271
channels, 298–307
converted from analog quantities to digital representations used by the Amiga, 269–70
creating, 267–69
cycles of a, 272, 273, 277–78
data representation, 272–74
loudness of a, 272–74, 290–95
multichannel, 297–307
period of a, 272, 273–74, 286, 289, 295–97
program to alternate between and use two channels for a, 301–4
program to alternate between channels with a, 298–301
program to use all four channels to produce, 304–7
system in the Amiga for creating, 271–74
volume of a, 286
waves, 267–68
Special Info structure for a proportional gadget, 172
Speech synthesizer, Amiga's built-in. *See* Artificial speech
Sprite(s)
animating the, 211–64
color and the, 219–20
in custom screens, 51

Sprite(s)—cont
defining a, 214–19
image data arrays and loops to change the shape of, 233
mouse cursor as a, 213, 214, 216–19
processors to control movements of graphics objects, 4
program to allocate and move a multicolored, 222, 224–26
program to allocate and move improved, 226–29
program to allocate and move two, 230–32
program to change the shape of the, 233–36
shape of the, 214, 233–36
Stack checking, disabling, 129
Start-up routine, LStartUp.obj, 24
Stress of a vowel, 344
String gadgets, 65, 71, 73–74, 167–69
Syllables, 312
Symbol table, creation of the, 16
System access, 14–25
System clock, 4
System gadgets built in to Intuition, 66–70
System software, access to the, 5–6

T

Tasking system to manage a process in memory, 127–28
Terminal-like interface of the Amiga, 3
Timbre of a sound wave, 268–69
Title bar
for menus, 92
for a screen, 52, 77–78
for a window, 39
Toggled menu items, 77
TrackDisk device handled by the executive kernel, 349
Translate( ) function to use the translator library, 313, 315
Translator library
to divide written words into constituent phonemes, 312–15
to encode written words into phonemes, 312
program to convert a character string into a phoneme string with the, 314–15
Translator library—cont
program using the narrator device and the, 317–19
TTY-style interface, 350

U

UndoBuffer, 74
UnloadSeg( ) AmigaDOS function to remove a program from memory, 132–33, 134–43
User interface
two types of Amiga, 3
Workbench Screen offers the standard Amiga, 33

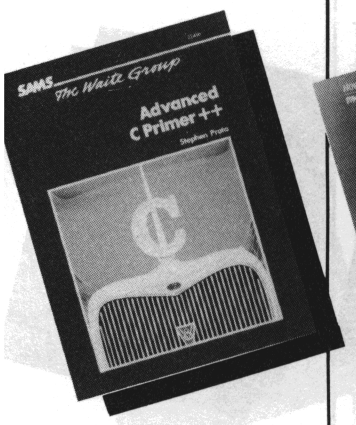
V

Variables, declaring and initializing structure, 113
ViewPort, position of a sprite relative to a, 223, 226
Virtual Sprites (VSprites) software sprites of the GELs subsystem, 236–39
library file of animation support routines for, 243–44
program to cause a single VSprite to bounce back and forth, 240–43
program to create and manipulate two, 248–51
program to make changes to a VSprite, 244–47
Voltages that drive the Amiga's speakers, 272–73
VSprite variables, 237–39, 251

W

WaitForChar( ) function to set up a measurement, 371–72
WaitPort( ) function to put the current task to sleep until a signal reaches its port, 125–26, 136
WaitTOF( ) command with a MoveSprite( ) function call to move a sprite, 226, 243
Window(s)
colors applied in a, 39
default settings for a, 39–40
defining a, 34–48

Window(s)—cont
each program has a virtual terminal of its own in its, 32–33
flags for a, 101
to handle input, output, and gadgets in Intuition, 31
positioning the, 39
program for creating overlapping, 40–42
program for opening a borderless, 43–45
program for opening a simple, 36–40
program for opening multiple windows of different colors, 45–47
Window(s)—cont
RastPort opened for each Intuition, 183
support file stored as a separate function for Intuition, 64–65
title created for a, 39
Windowing system of the Amiga, 3
Workbench Screen, 33–34, 39, 132
Workbench system utility to start a process, 132–48
Wgets( ) function to initialize a parameter string, 108–9
Wputs( ) function to place character strings in a window, 108–9
Write( ) function to return the number of bytes placed on a file, 354–55



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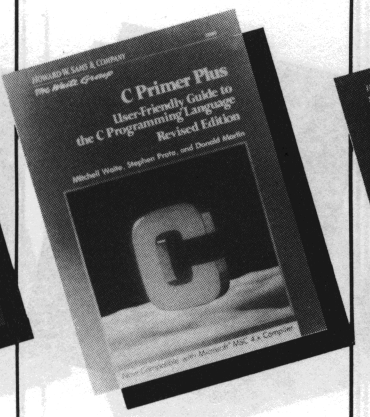
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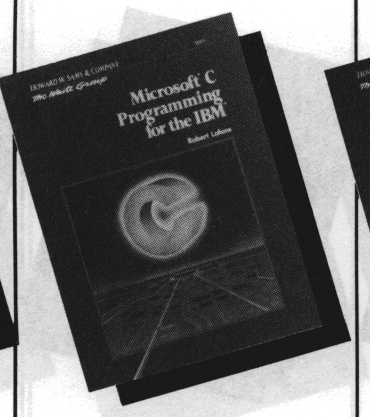

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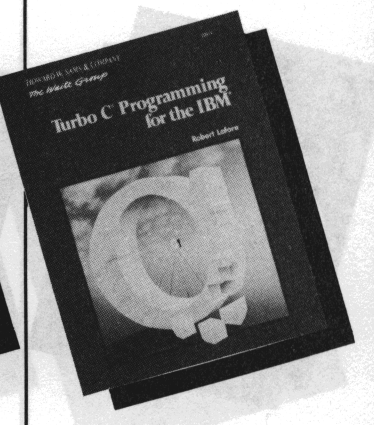

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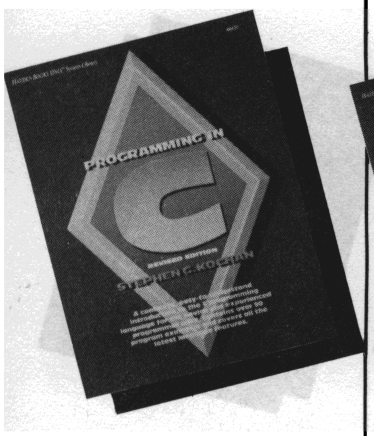

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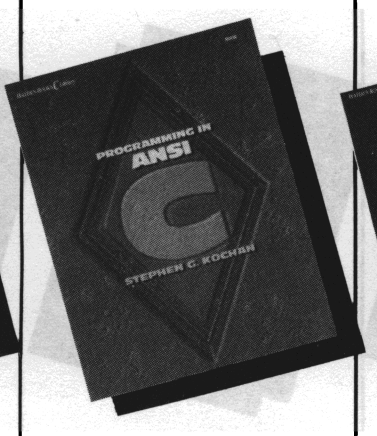

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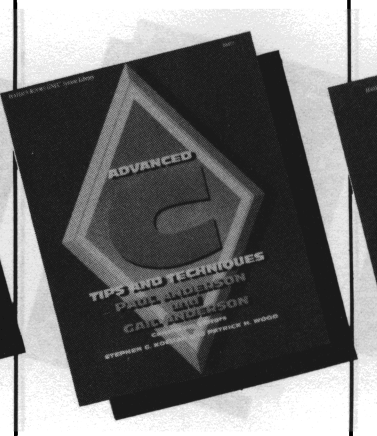

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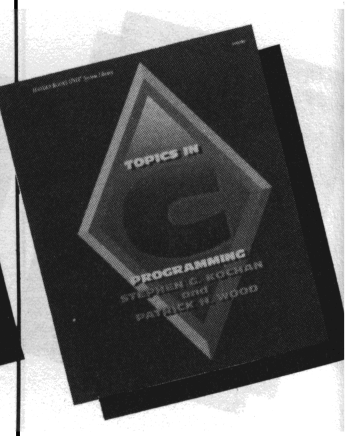

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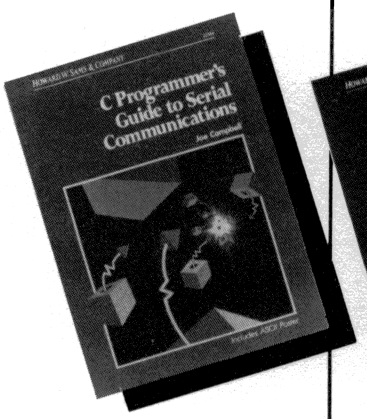

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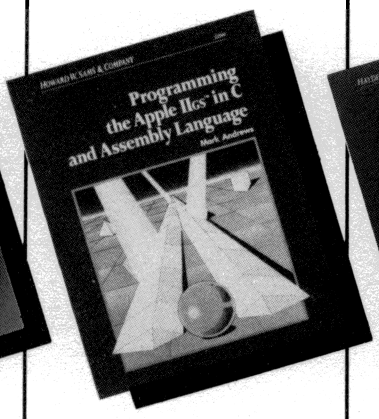

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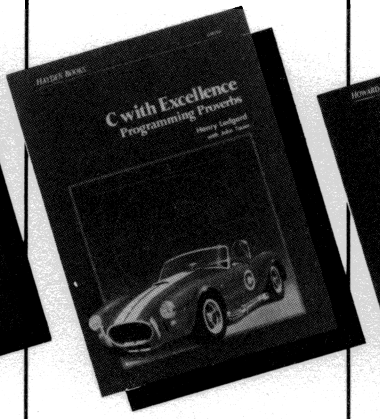

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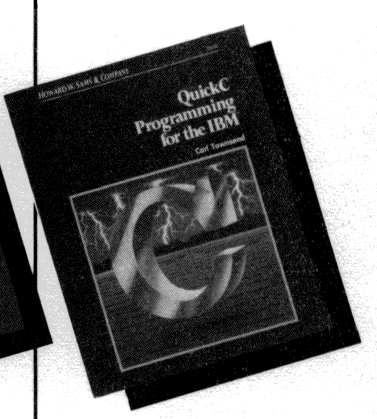

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